Architectural Articulation and Configurations of Space: Advancing theory, principles and bases for spatial modelling

264-1

Architectural Articulation and Configurations of Space

Advancing theory, principles and bases for spatial modelling

DANIEL KOCH

KTH School of Architecture | Chalmers Civil Engineering and Architecture

daniel.koch@arch.kth.se | daniel.koch@chalmers.se

ABSTRACT

Space syntax has established itself as a significant field of research into architectural and urban phenomena through the analysis of spatial configuration. Analyses that predominantly consist of variations on modelling spatial configurations as systems of axial lines, segments, convex spaces or isovists with further refinements. This analysis builds on the process of, as stated in the Social Logic of Space, first making discrete units out of continuous space, so as to create a system that can be analyzed, and then subjecting this system to analysis. The procedures of creating these discrete systems have seen many iterations, lately often employing a range of processes to road center line maps or similar existing geographical information or, increasingly dominantly for buildings, VGA analysis where isovists are distributed evenly in a grid in the space subject to analysis. This has allowed for more rapid analysis of larger sets of data and ostensibly less impact of human decisions in constructing the analytic models. At the same time, theoretical developments have increasingly looked to cognition to explain statistical results and to theorize the spatial units employed in syntactical analysis. This work has been important for the field. However, some important questions still await robust theoretical reconciliation. For instance, isovists, argued for as representation of vision, are employed both to analyze visibility and accessibility while the scale and type of object or material boundary that is considered a boundary in an axial line or convex space map varies. This article does not strive to provide a final resolution to these challenges, but discusses and refines the theoretical basis to provide potential paths forward. In this discussion, the article compares spatial configuration as the understanding of the combination of construction of pre-defined entities to spatial configuration as the result of subdivision and articulation of spatial differentiation in several ways, which incorporates cognition as an active faculty that operates in relation to intent and background of whomever is concerned, but also allows to consider the potential of different cultures embedded in cognition through notions of salience and articulation. It suggests that some of the difficulties in finding a clear-cut definition of e.g. ‘convex space’ lies in that rather than a geometric property of ‘space’, one might look to their formation and articulation by material boundaries as culturally and situationally conditioned. This allows for a more dynamic yet not completely relativistic theoretical ground for developing analytic modelling further and meeting challenges that are yet theoretically unresolved.

KEYWORDS

architecture theory, spatial configuration, cognition, spatial models, diagramming

1. INTRODUCTION

Space syntax has established itself as a significant field of research with a wide array of findings related to a core investigation of the role of spatial configuration in various ranges of individual, social, cultural, economic, and other processes. In this research, modelling ‘space’ in ways that via transformation of more or less continuous space into discrete units for study as graphs has been a

central strategy, where the method of analysing these graphs increasingly lies in mathematical analysis related to systems theory. One can even argue that the particular translation(s) from 'space' to 'graph' is what enables a large part of the findings of the field in that it allows for qualitative and correlational testing of hypothesis as well as investigative work.

Translation from material space to graph is not a trivial matter, however, and making discursive what constitutes 'space' for the purpose of analysis has been central, where interdependency of social and spatial relations is key (Hillier and Hanson, 1984). This differentiates the fieldfrom many other graph- or diagram-based models (e.g. March and Steadman, 1971; Klein, 1927; Leuder, 2017; Alexander, 1964). While translations have been developed in several ways (e.g. Hillier et al., 2012, Peponis et al., 1997; 1998; Hillier and Hanson 1984) and continuous refinements are made (Morello and Ratti, 2009; Bhatia et al., 2013; Varoudis and Psarra, 2014; Hwang 2013), one might note a tendency towards convergence to a particular subset of models, methods and techniques and a tendency to make slightly too quick links between theoretical arguments and applied models. In many practical situations this might not pose a problem, but for the field's development it is important to closely examine and refine theoretical aspect not only of space-society or space-individual links, but of the particular role of the analytical spatial models and their translations from built form.

However, while there is continuous theoretical refinement in the field, there is unresolved terrain between the theoretical discussions examining and explaining the models and models used (or made) in practice, and, conversely, between the way models are made in practice and their common theoretical explanation. This article intends to explore this unresolved territory. To a certain extent this requires deconstruction of both theory and practice, which always runs the risk of a sort of Derridean dead-end or, as does Tafuri's (1968) investigations, to end up with that since all positions can be questioned no position is possible. While not engaging with the general validity of such arguments, they clearly suggest the importance to more firmly establish links between theoretical positions and modelling practices. Following such a line of reasoning, the target here is to move theory towards a firmer discursive ground for analytic modelling practice. The intent is thus not to 'solve' modelling in practice but to refine and develop the *theoretical basis of the particular link* between the geometry of space and the configurational models of analysis.

Through examining theoretical and practical challenges and refining links between modes of translations and theoretical positioning, it will be suggested that rather than insisting on particular models as 'better' or 'worse', questions of which type of model and the definitions and decisions in its making works better must be distinctly tied to research query and situation. This, it will be argued, necessitates theory that makes explicit not only modelling decisions in practice but their relation to theoretical positions and consequences, and relations of theoretical 'ideals' to limitations and possibilities intrinsic to models and modelling practices. This must be done critically and with care, as it is important to not confuse 'highest correlation' with 'best theory' prematurely, as that would lead towards the simple case that, as we know, a model that is made directly after observed socio-spatial practice will best correlate to this socio-spatial practice but essentially be a tautological rather than an analytic model.

It must also be acknowledged that the argument comes from a theoretical position as well as a position on the purpose of modelling is (e.g. Downes, 2011; McCarty, 2008; Marshall et al., 2018). This position is one from architecture, which in some respects deviates from one of, for instance, environmental psychology or geography. A differentiation I believe to be best clarified through the coming discussion. And while I acknowledge that the fields are interlinked, the difference can be crucial as it brings the particular state of architecture as having been *made* into play.

Finally, the type of argument to come necessitates drawing out and extrapolating tendencies to highlight differences and challenges. My intentions in simplifying is thus not to neglect all the important work performed, but to distill what questions are at stake. It is also not the intent to simply criticize the field for developing largely through learning in and from practice—I will argue the contrary. It is, however, critique in the sense that it intends to raise questions of theoretical and methodological positions and the links made between analytic models and empirical findings.

2. OUTLINING SOME CHALLENGES

As Bafna (2005) points out, the analytical models in space syntax concern a particular take on what one might call 'material architectural space'. That is, in a wider context space can validly be discussed

in a range of different ways, where the particular notion of how it is organized by material boundaries is decidedly architectural (Peponis, 2005; Marcus et al., 2013). This means that the field investigates geometries in the sense that while the analyses are 'a-geometric' (though topology is a form of geometry) and it can be argued that the geometry of spaces are not subject to syntactic analysis, this is only partially true as the definition of the topological units of analysis derive from the geometrical shape of their material boundary. Sophia Psarra formulates is as that

> "[…] integration is influenced by varying degrees of geometric control on the patterns of visual information. Spatial configuration is dependent on the relative placement of physical elements. But in spite of coordinating axial lines, convex spaces, isovists and their interconnections, form in space syntax is buried under the notion of depth and changes of direction." (Psarra, 2010, p.22)

From this point of view, one can see remarkably little discussion lately that focuses particularly on the translation from built form in the sense of the material acts that shape boundaries of 'space' to spatial units in a graph. One can find work that concern relations between analytical models and cognition in several aspects (Peponis, 2012; Hillier, 2012; Hillier and Iida, 2015; Marcus, 2018; Dalton, 2005; Emo, 2017; Koch, 2005; 2012), but also on modelling practice and how to measure, for instance, distance and other aspects of subsequent analysis (Stavroulaki et al., 2017; Figueiredo, 2015; Jiang and Claramunt, 2004; Peponis et al., 2008; Turner, 2003; 2009; etc.). These have different approaches in many aspects, but by and large they share the general approach of comparing maps 'as they are', and the overall discussion tends to concern moderating the degree of unit aggregation, the measures of 'distance', or the formulae to calculate centrality (or other mathematical concepts).[1] When they do address the theory-model-reality relation they tend to do it on the level of basic principles. As an example, the use of RCL maps instead of axial maps to produce segments is verified by that above certain scales they generate statistically correlating measures, or correlate statistically equally well to pedestrian movement flow counts, which is subsequently used as validation for making use of the theoretical foundation of one as argument for the other (Turner, 2005; 2009; Krenz, 2017). This is more or less a test of situated robustness between models (Sugden, 2000), which rather than showing interchangeability demonstrate that they can serve in place of one-another *within contexts and for queries for which the test of robustness is valid;* i.e. where the correlation supports that results of the research inquiry at hand would not significantly deviate depending on which of the models is used.

The inquiry here concerns how decisions constantly need to be made when creating the models 'themselves'; inclusion or exclusion of roads without pedestrian access, how to model complicated intersections or highly trafficked roads, what kind and scale of boundaries or objects break axiality, and so on—or how to balance 'probable' versus 'possible' in the colloquial 'lines that people can see and move along' definition of axial lines. One might argue comparatively few axial maps follow the stricter geometric definitions generally used in theoretical arguments for the basis of their validity. This has of course not been just ignored; rather there are a few practices of drawing axial maps developed which are commonly employed, and while I argue that they have not been theorized this is not the same as that they have not been discussed and critically examined. These practices are based on combinations of informed reasoning, theoretical principles (grounded or hypothesized), and principles inferred from observations. In this sense most manually drawn configurational graphs balance between testing principles (deriving models from distinctly theoretical principles to see how they relate to observed phenomena) and learning from observed practice (adapting what constitutes a boundary from what people are observed to treat as a boundary), which is also true for ostensibly automated graphs such as the VGA graph that requires preparation of drawings and decisions of what objects to include as boundary definitions. The challenge is to theorize this productive diversity of modelling practices that currently operates as a non-discursive 'glue' in the field, rather than striving to reduce these in order to enforce a particular modelling orthodoxy.

An interlinked challenge is that *spatial* models by default are quite precise. By this I do not mean that they measure precisely what one tries to find out, but that in order to do a spatial analysis the model becomes precise in its internal definition. Where and how points, lines, paths, boundaries or other elements are distributed gain a certain specificity due to decisions embedded in the model's construction. Some of these challenges include specifically geometries and the formulation of space

[1] We need to distinguish here between, for instance, if an angular deviation in a model should be considered or not (e.g. continuity, threshold) and if the model should include the boundary that generated the angular deviation in the model to begin with. This question cannot be resolved within a model but reside in modelling practice and construction rather than operations on any given model.

and boundary, as in the often referred to criticism by Ratti (2004), but also how the definition of convex space leaves a number of plans impossible to resolve (Penn et al., 1997; Miranda and Koch, 2013). Even though geometries that lead to these challenges, as argued in Hillier and Penn's rejoinder (2004), rarely occur in reality, some of the challenges remain unanswered. Whether models of for instance park environments should follow the assigned pedestrian paths or be allowed to pass over grass surfaces remains an unresolved territory of discrepancy between theory and practice, and use of RCL does not resolve these challenges as it simply shifts the hands of making these decisions. Similarly, there have been attempts to resolve the challenges of convex space definitions but the theoretical-geometrical grounds for a wide and solid practice of generating informative justified graphs remains unresolved.

Pointing out these challenges is not questioning whether spatial configuration and modelling thereof holds social and cultural significance. My position is that we with certainty can say that configuration *matters*. The way space is organized by material boundaries has effect, and is both directly and metaphorically linked to spatial cognition, social organization, cultural values and economic processes. The models developed are informative and descriptive in a range of ways and for a range of research questions. There is definitely *more* to learn on these questions as well. This is not the question. The question is to return to the theoretical basis of the analytic models to refine *the particular link* between theory and practice in the translation from material form to model of space. The challenge can be formulated as such: most models used to verify configurational analysis empirically are inconsistent or contradictory to their theoretical explanation. Conversely, the theoretical argumentation for models makes use of cases and models that are not directly translatable to the ones used in analytical practice.

3. MODEL BASED REASONING IN (SCIENTIFIC) DISCOVERY

Even if exact definitions vary between disciplines, 'models' generally share some principles in that they are abstracted representations intended to investigate or clarify principles and relations (Downes, 2011; Sugden, 2000; McCarty, 2008). They have an indirect relation to 'reality' (Magnani et al., 1999) as well as to theory. Hanson and Hillier (1987) points to the danger of correspondence thinking between social concepts such as 'community' and spatial concepts when trying to implement socially relevant knowledge into built form all too readily in a 1:1 relation. It is of equal importance to not confuse the isovist for vision, or to assume the relevance and empirical validity of any model to mean that it 'exists' in the lived and perceived in the same shape and form as found in the model. Gilles Châtelet (2000) provides the example of pressure lines in water as true but non-existent: *if* one would be able to create a surface in a jar of water after a drawn pressure line, water would indeed provide pressure on it as the mathematical-diagrammatical gesture of the pressure line suggests. In that sense they are 'true'—but in practice there are no pressure lines of that kind, save that *all conceivable* pressure lines 'exist' simultaneously. They are simultaneously both true and unreal, but enable deeper understanding and explanation of water pressure phenomena (see also Svetlova, 2015).

From the same point of view, whether an axial line exists is inconsequential on the one hand, but important on the other. They do not need to 'exist' in any common sense of the word to be valid for modelling but like pressure lines they 'exist' without 'being there'—yet nothing in their existence in that sense that will validate or invalidate their relevance. This is the position I take in this article: the 'real existence' or 'truth' of the analytical models is not a point of inquiry. Rather, considered as models for scientific discovery and methods to expand, explore and strengthen our understanding of relations between space and society, they are remarkably productive and can feed into many empirical as well as theoretical challenges as well as generate even contradictory theories and explanations (see for instance Montello (2007) and Seamon (2015)) because they hold a particular intermediate position between 'theory' and 'reality'.

With this said, it is important to acknowledge that models need to be comparable for results to be comparable, which depending on question puts demands on their internal as well as interrelated logical consistency. Examining trends in building depth as Manum (2006) and Peponis (2012) or between homes as Hanson (1998) has done, for instance, requires consistent modelling within the sample to ensure that found differences are not simply differences in modelling techniques. This has been further elaborated in-depth by Stavroulaki et al (2017), Berghauser Pont et al. (2017), and Marshall et al. (2018) in investigating differences in geographical information in different cities and what this means for translating existing geographical models to configurative models. The question is what constitutes consistent modelling.

If we insist on the status of the model in research to be neither the ideal of theory or direct representations of 'the real' (Knoespel, 1999; 2002), there is ground to continuously refine and verify the varied set of models' ranges of validity. That is, to develop knowledge by treating configurational and spatial models of syntax research as models in a wider set of research—as intermediate, medium, testing ground, and translation between theory, 'reality', experiment, validation, explanation, and challenge; i.e. as sites of interrogation, explanation and discovery (Raisis, 1999), where models hold "a ternary relationship in which it mediates epistemologically, between modeler and modeled, researcher and data or theory and the world" (McCarty, 2008, p.255). As such intermediates, models form a particular kind of hypothesis-making, testing, and site of experimentation: as being abstractions they always discard information in order to investigate chosen aspects of something. These abstractions are not better or worse depending on detail, complexity or direct correspondence with 'reality', but depending on their explanatory power (I here do not differentiate between explanation and understanding) of chosen aspects and interrelations (see e.g. Sugden, 2000; Godfrey-Smith, 2006; Downes, 2011).

To a certain extent, space syntax is a school example hereof, in its oscillation between (informed or hypothesised) speculative modelling, discovery of phenomena in the model and 'reality', investigation and validation of relation them in-between, and theoretical development in response to these findings. As the story goes, the models also largely precede the findings; at least as concerns convex spaces and axial lines, their initial construction and definition is closer to a model hypothesis or hypothetical model than an attempt to model directly and accurately human cognition or spatial actions (Hillier and Hanson, 1984). The field is, however, particular in the sense that its models have an ostensibly direct relation to the material world and superficially it may seem as an actual mapping thereof. This apparent closeness between 'model' and 'reality' is both a strength and a danger, as it might push thinking towards that the more the model resembles the totality of reality the better it would be. From such a perspective, one must be clear what it is that is being modelled, as well as how this is understood.

4. MODELLING THE INQUIRY: SYSTEMS SCIENCE AND (POST)STRUCTURALISM

After a period of operating closely with systems theory, it has lately been acknowledged that the roots of space syntax might primarily be found in (post)structuralist thought (Hillier and Hanson, 1984). These theoretical bodies share traits but have different fundaments. Systems theory and (post)structuralism agree that the meaning, role, importance, or character of any part of a system or structure is defined by its position in the relational structure. However, what constitutes a unit, how it finds its place in a system, and how it comes to be to begin with are fundamentally different. Simplified, one can say that in systems theory, a *network* is constructed by *nodes* and *links* where, importantly, the *nodes pre-exist the system* or exist independently of the system no matter how dependent they are of the same for their character. In (post)structuralism, even though one could speak of nodes and links, it is rather relations that are investigated, where entities are *dependent on* the structure in that they are carved out of the whole through a process of differentiation, and the *processes and structures of differentiation* are the key points of inquiry.

To not get stuck in further refining this difference, one can translate the positions into how 'space' is considered into two base hypotheses for research inquiry: the *fundamental unit hypothesis* and *the procedural differentiation* hypothesis. These are not posited randomly but relates distinctly to linguistic paradigms, just as space syntax rests (uneasily) in linguistic paradigms. But they can also characterize strands of research within the field: Marcus and Koch (2017) present space syntax as possible to explain from two sides—the cognitive explanation and the social explanation. While this is illustrative of tendencies in the field—research linked to cognition tend to adhere closer to systems theory while research linked to sociology tend to tie closer to (post)structuralism—it must be seen rather as a shorthand for describing how two contradictory positions exist simultaneously, where both may be valid depending on research inquiry. This points to a pressing question for syntactic research, in that it investigates relations between an individual and its actions, perceptions, and possibilities in relation to the environment on the one hand, and on how two or several individuals understand, express, negotiate and navigate their interrelations through encounters and avoidances in the environment on the other, where links between need further refinement. It is my position here that one is not a special case of the other, but that they are interrelated as it comes to theorizing, modelling, analyzing, navigating, experiencing and cognizing architecture; the way we structure information about architecture *incorporates always-already* our understanding of how architecture relates us to others, and others to each other.

Simplified to syntactic research practice, the question that grows forth is whether for instance 'convex space' is a *unit that pre-exists its being defined by boundaries* or if it *grows forth as a result of spatial differentiation*. This includes how space is conceptualised in architectural design where different architectural traditions would be posited differently (e.g. Hillier, 1996; Forty, 2000; Emmons, 2006), but also how we interpret research findings as well as how we relate to modelling practice not only of individual units but of *spatial configurations.* If we again simplify the query, the question can be posed as whether one navigates a building by understanding how its units ('spaces') are composed into a system of rooms, or by understanding how the building's volume has been differentiated into 'rooms' by material boundaries. Any answer puts the demands on research and modelling differently.

A well-established example of such modelling challenges concerns how to divide Mies van der Rohe's Barcelona pavilion into convex spaces. By the base definition of convex space maps it might seem impossible (Psarra, 2009); an impossibility that is interrelated to how Benedikt (1979) shows that while it is possible to identify a minimal set of isovists to form an interconnected circuit of visibility, there is no way to define just where the origins of these isovists should be. Similarly, the pavilion can be found to be configured by a certain number of convex spaces linked into a certain configuration, but we cannot define just where one space begins and the other ends. We can also look at the analysis of the Rolex Learning Center by Marcela Aragüez and Sophia Psarra (2017) to find an architecture that poses theoretical challenges for how to model which increase the more one insists on identifying specifically these boundaries, as spaces are defined by an undulating landscape floor and unclear boundaries in terms of visibility and permeability. As Miranda and Koch (2013) show, there is no self-evident 'best' here although systemic principles or relative measurements seem to perform closest to manually drawn convex maps. But as they point out, more consistent testing is needed that ought also be against other material like for example observations of occupation, interview data (e.g. Giuliani, 1987) or social organisation mapping (Markus, 1993; Dovey, 2008).

That is, if one's concern is finding a specific line separating two spaces, one might find it is, indeed, geometrically sometimes impossible. This does not exclude the possibility to define an organization of least number of spaces to describe a system, and their interrelations. That is, we can extract an organization without having definite boundaries of the units. This can of course be problematic if the question is in which space a particular activity takes place—but it may also be informative: architecture with many zones that could fall into different 'convexes' is different from one with few. This question of boundaries and units can be further understood via Heinrich Wölfflin's writings concerning Rembrandt's painting style.

> "Within Rembrandt's work, there is a distinct development. Thus the early Diana Bathing is still modelled throughout in a (relatively) plastic style with curved lines following the separate form: in the late female nudes, on the other hand, little is used but flat lines. In the first case, the figure stands out; in the later compositions, on the other hand, it is embedded in the totality of the space-creating tones." (Wölfflin 1950, p.23)

Wölfflin argues that the change in style is not a question of painting technique or poorer eye-sight as much as a change in how Rembrandt views the *motif*. In the earlier work, rather than having more precision or detail, aspects like the outline or contours of people are *foregrounded* and *exaggerated.* There are shadows and lines around the bodies that from a photorealistic point of view do not exist, as well as lighting effects that do not follow from the situation but ensure the reading of each individual body as separate. On this basis, Wölfflin argues that in the early works, Rembrandt was concerned with people as 'essential units', individuals pre-existing the event and independent thereof subsequently gathered into the depicted situation, shown by how they are articulated and exaggerated as separate entities artistically. Conversely, in the latter works Wölfflin argues that Rembrandt is concerned with people as intrinsically defined and subjugated to the situation, artistically expressed in vague boundaries and fleeting transitions from one to the other, where shadow, light and colour is used to sometimes make difficult to read where one person begins and another ends. Wölfflin's attempts to translate the reasoning to architecture tend to take rather simplistic forms and is therefore not the point (see Koch, 2007)[2], and neither is whether Wölfflin is right or not regarding Rembrandt's development. The point is how it highlights how the difference in definition of involved elements and

[2] Rather than look at the appearance of boundaries through their material formulation (such as walls), one could look at the boundary character through how configurative structures appear with easily definable boundaries or in transition zones or other forms—acknowledging that from a *modelling* perspective a linear boundary can appear whether there is a wall or not. This inquiry leads further into how one relates to the individual topological units and their location and extension in the plan, map, or diagram that is their origins.

their boundaries can be understood as defined by as well as defining the understanding of the whole. Do we read configuration as a question of the 'linear' (composition of entities/spaces) or the 'painterly' (differentiation of a whole)?

The point here is not the boundary in its material formulation, but the demands the underlying notion of the motif and the unit puts on its mode and precision of definition as well as how it affects and is affected by the understanding of that which is modelled. If one must be able to precisely outline the contours of the unit, because the *unit* is the basis of analysis, then precision in modelling concerns their precise boundaries; both exact location of the boundary and specific definition of the unit must be clear. If one is concerned with differentiation that is interdependent and fleeting in boundaries, then the question is less concerned with precisely defining boundaries and the analysis can be satisfied with identifying the number of elements and their relational structures. This is not to suggest that the boundary would not matter in the latter case, but it would only matter *in altering the interrelation of elements*. This has two further implications. One is that different theoretical positions would necessitate or dismiss attempts to define exact boundaries. This includes theoretical position in systems theory or post-structuralism on the one hand, but also (and interlinked) theoretical position concerning space and its mode of definition on the other. Whether to impose linear boundaries or not would either relate to the research inquiry or ontological position of the research(er). As follows from Wölfflin's argument, how one relates to these boundaries reflects how one understands [space]. The other is that for certain kinds of work such an act would be violent, in that it enforces upon an architectural work an interpretation that is contradictory to its artistic intents.

Rather than uniformly resolving the problem by enforcing a particular form of boundary it is then possible to internalize the challenge as a qualitative component of the modelling theory and practice as such (e.g. is the architecture of clearly defined or fuzzy (geometrical) boundaries). But the treatment and definition of 'boundary' in this sense only deals with part of the problem discussed in this article.

5. EXAMINING 'COGNITION'

While the current argument is not directly concerning cognition, cognition has grown an important body of research on which syntax research has productively developed its theory building. It has seen a wide use in syntax research set in relation to for instance cognitive maps (Dalton and Bafna, 2003); as theoretical basis focusing on the cognitive logic of turns and vistas by Peponis (2012); in relation to Gibson's (1986) theory of affordances by Marcus (2018); Hillier and Iida (2005) substantiating the link via statistically testing movement flows against configurational measures; Dalton's (2005) research into cognition and navigation; investigations of isovists as egocentric representations by Emo (2017); or Penn (2003) addressing the axial line as a cognitive element. Unresolved differences them in-between seem productive ground for future research, but acknowledging them is important since while cognition concerns links between mental processing of information and material spatial structure, it is not an argument for *a particular form of perception* or, for that matter, *a particular type of spatial cognition* (egocentric, allocentric; Hillier 2003; further Portugali, 2011). Neither is it the case that just because an individual unit can be argued for in one of these perspectives, that this is necessarily the explanation in all instances of their (systemic) use.

Cognition concerns the mental action or process of acquiring knowledge and understanding through thought, experience, and the senses. In this sense, cognition is 'individual' and there is a range of ways in which this makes it valid to distinguish from 'the social' while simultaneously impossible. However, to leap from this observation to that cognition *concerns* individuals is premature in several ways. As argued by for instance Tversky (2003), it needs to be recognized that spatial cognition is situational in that it depends on 'why' cognition operates. Tversky writes about the different 'spaces of the body' as space around the body, space of navigation and space of graphics. In a similar vein, Richter, Winter and Santosa (2011) show how amount of detail in mental spatial representations differ according to purpose and stages of a journey so that the cognitive map of a campus layout may operate as simply 'campus' for large part of a journey *to* a campus and only be further refined once having arrived on-site. They show how changes in such granularity in cognition is not directly or gradually related to closeness but can happen in distinct shifts, meaning that technically inconvenient routes are used since the layout of, in this case, the campus might not be considered before arrival leading to what in utilitarian terms might be a detour. Koch (2005) further demonstrates how objects of the same type and scale—e.g. bookcases that blocks sight—have demonstrably different impact on movement patterns in different public libraries, indicating that the relation between architectural

articulation ('the building') and internal furnishing varies, though it remains to be answered if it depends on subordination of ordering or relative information structures; do the bookcases have effect because their arrangement deviates or conforms to the structural logic of the library, or because in one case the building offers clear and concise support for orientation and not in the other?

From a *cognitive* perspective, it might therefore be said that *'inconsistent'* object scale is *cognitively consistent* modelling, *if* the difference in included boundaries correspond to the same type of cognitive action. That is, if cognition serves to interpret boundaries in the environment dynamically depending on both intent and environment to construct an understanding of the space of affordances or navigation in a given situation, and if a 'typical' case of walking engages with building boundaries in one environment and pedestrian path boundaries in another, then the model would be consistent from a *cognitive* perspective if it responded to these changes. This is *not* the same as whether people actually *follow* these boundaries or not. Just as the validity of the axial line as such is not dependent on people actually walking along it in a *direct* sense.

To engage with this relative ground of boundary definition and indeterminacy I think it is of interest to raise the cognitive notion of *salience.* Salience stand for, in short, the emergence of *shared* and *reoccurring* ways of relating to and conceptualizing the world and is used in cognition for instance as concerns categories. A category is *salient* if it is shared by many and/or reoccur pervasively. Salience is thus not a matter of correctness but if something is embedded in cognition in a culture. For example, it has been shown how different cultures differ in how they structure categories of trees in both degree and kind of differentiation (Dougherty, 1978). A difference that is not only one of naming species, but of cognitively recognizing them as different or not. As cognition is mental processing of information, and memory is a dynamic and active faculty that restructures itself continuously (Kaye, 2000; Bondolilo and Pillemer, 2015; see further Koch, 2017a), it is only reasonable that the same is true for spatial information. From this perspective, it is additionally reasonable that information is transformed depending on level of knowledge and familiarity with a particular environment as well as with similar environments in general. Thus, cognition suggests we need to investigate differentiated ways of modelling and of interpreting results, not only as egocentric or allocentric spatial understanding (and lately altercentric; Surtees et al., 2013), but as cognition treating space differently depending on situation, purpose, degrees of familiarity and cultural conditioning. This is not only in the sociogeometric or 'use' sense but in how the models are structured as well as the role of a subject or body within them, as introduced in the previous section.

This posits cognition interconnected to four different conditions. (1) Cultural differences in what information to include or discard as spatial differentiators, (2) Differences in architectural cultures that impact the same, (3) Differences in the material formations and what type and amount of support it provides for cognitive processing, and (4) Differences in the situation and purpose from which cognition is operating. This is not a query that is resolved through further detail, or through the use of one model type or the other. How would one then move from such a position towards solidifying modelling practice?

6. ARCHITECTURE CULTURE

Architecture as built structure is a cultural artefact; whether 'vernacular' traces of collective habits or practices, solutions to practical problems, or the result of self-conscious and deliberate design work to create something specific or unique. As argued both within and outside of syntax theory, it holds an indirect but strong relation to its inhabitation, be it in how it manages social relations or how it guides movement and experiences, creates differentiations and structures capacity, control and surveillance. As such, it is embedded with choices and prioritisations amongst the many *different* designs that would solve the problem at hand, where any solution by necessity includes prioritising amongst conflicting goals and possibilities yet allows a lot of freedom in subsequent use (Krippendorff 2006). Looking at architecture as culture in a historical and regional as well as in an aesthetic sense, priorities are different as are their modes of realisation. Such an ostensibly 'functional' thing as vernacular homes, cannot be explained based on 'functional' or 'basic' needs, as even if they in some senses do respond to such, the way they do so differ radically depending on the social and cultural conditions of their becoming:

> "Contemporary literary and sociological studies of people's homes were unearthing a wealth of evidence that space configuration featured in British society in surprising, and often unexpected ways, as a means of social and cultural identification. The manifest variety of

> ordinary people's lifestyles seemed to point away from behavioural universals and basic human needs towards a view that, if space had a purpose, this was to encode and transmit cultural information." (Hanson, 1998, 109)

The same could be said of many other types of buildings, such as factories, schools, and even whole cities (e.g. Peponis 1985, 2017). The somewhat unstated issue here, intentional or not, that I intend to unpack is the relation of this statement to architecture being culture. Hanson's statement thereby means that one of the purposes of [architecture] space is to encode and transmit architecture. That is, if architecture is culture then one of the roles of architecture is to encode and transmit itself, which may sound a tautology but I will argue it definitely is not. Rather, as intrinsically linking the material and the social, architecture serves to encode and transmit information of its own state of being, its purposes, its rules and uses, and its modes of operation. From a spatial configuration perspective, it communicates *how* it articulates differentiations and spatial divisions, and *what kind of articulations* formulate spatial boundaries.[3]

This is not saying that the role is to communicate itself in terms of the meaning of a particular building—just as Hanson is not saying that it is the particular values of a particular family constellation that is communicated. It rather operates on another more indirect and arguably more structural level of meaning. From a linguistic point of view, one could argue that it communicates principles of differentiation and structures of *morphemes,* of *semiotic differentiation of signs,* and *syntaxes* of combination. Some of these emerge as pervasive or salient, whereas others are less common and some might be near unique. Relating to a labyrinth is different for one growing up with labyrinths as a common spatial practice and one who rarely ever encounters one in everyday life.

The suggestion of architecture as culture includes the differentiation of architecture cultures in terms of how subdivision or definition of space is understood; i.e. is a minor protrusion from the wall such as a pilaster separating a hall into two spaces or not? It is reasonable that this is relative to both culture (are pilaster forms used, and are they used to signal spatial differentiation or not?) and context (is it in the particular architecture an anomaly in otherwise smooth walls?), but also to generic modes of spatial separation (are walls extensively or sparsely used compared to other territorial markings?). The balance between spatial formation (shape and geometry of 'space') and architectural articulation (material formulations to indicate difference) in such cultural difference is also likely to vary. The use of 'architectural cultures' here suggests, intentionally, the twofold possibility of this being between 'cultures' in a geographical or historical sense (e.g. classical or medieval, European or Mesoamerican, etc.), or between cultures of architecture such as international style and national romanticism. While one should be careful to assign causal links between environment, technology and social and spatial practice (Foucault, 1982; Wigley, 1995) one *can* investigate how environment-technologies-practices bundles participate in formation of architecture culture to, arguably, produce ecologies of self-to-environment relations that are observably different in part related to the material culture of architectural production.

The suggestion is here rather simple: within certain boundaries conditioned by architectural acts of creating difference and connectivity, what constitutes a spatial differentiation might vary between individuals, cultures, and aesthetics, and this means that analysing 'spatial configuration' in different cultures might require different modelling rules. If architecture communicates culture and thereby itself and its own principles, then what constitutes a boundary is part of this communication. The basis of syntactic modelling would then need to incorporate analysis of the modes of spatial articulation active in the architectural culture analysed. But also that there is a culturally dependent scalarity and layering within which bundles or clusters of spaces are, or can be, treated as singular units. A division of this kind that is more or less accepted in syntactic research is between 'buildings' and 'public space', even though the relevance of this definition depends on cultural factors and the field itself has demonstrated that there are many cases where additional differentiations of similar kind show both theoretical and empirical significance.

---

[3] One might here raise the question whether space syntax is intended to avoid embedding cultural differences in the modelling choices and rather see such emerge as results of analysis. The answer to whether this is possible is both epistemological and ontological. However, as I understand it from *The Social Logic of Space* (Hillier and Hanson, 1984), the answer is a distinct *no*. The separation between material space and 'the social' or 'use' is one of methodological and practical necessity, operating under the fundamental position that space is inherently social and the social inherently spatial for there to be any possibility of there being an interrelation. This is not, however, to ignore that the success of the methodology is dependent on consistency and clarity in this separation, or that it is important to avoid arbitrariness in subdivision.

This links closely to aspects of aesthetics that might tie the discussion together, providing one does not pretend that it is the response to aesthetics in architecture. Aesthetics not in terms of preference, but in the sense of positioning of the subject to make a work of art meaningful, and different aesthetics thereby conditioning different modes of relating to [architecture] (Kaye 2000, Kant 1974, Koch 2017b). That is, understanding architectural affect to make us relate to it in ways that makes it make sense, even if what that 'sense' is might differ. Drawing from the discussion above, configuration is *also* a question of aesthetics, even if one must be careful to not subscribe either (aesthetics or configuration) to the other, not only in the direct sense but in how it affects and conditions subjectivity. Some of this aesthetic conditioning is intimately tied to habits (Ballantyne, 2011), constructing relations of self-to-environment embedded in subjectivity as well as action forming aesthetics in conditioning the subject and its relation to the world over time that establishes *a* (as opposed to 'the') meaningful relation that includes understandings of self-to-self and self-to-others. This takes place both in a specific or general sense, and as an adaptive and dynamic ability which evolve over time that can be (and is) trained. Architecture forms a form of non-discursive training (Bourdieu, 1984) in capacity to relate to 'itself' as specific buildings or environments as well as to architecture in general.

Claiming the importance of training is not to subscribe to complete relativism. As Judith Butler (1999; 2005) argues concerning identity, while there is no evidence pointing to that there is such a thing as a pre-existing subject which finds itself and most evidence points towards subjectivity as constructed, this does *not* mean that it is 'false' or 'unnatural'. Rather, subjectivity can be a reasonable outcome of being human in society: as we learn to recognize 'ourselves' as actors in the environment as different from other actors, we incorporate into this understanding of our selves an understanding of how what 'I' (that is, one embodied being in the world) am is not the same as another 'I' as well as that while part of the 'world', this 'I' can also affect or be affected by it. It is reasonable that such subjectivity includes the environment, and that there are some general logics to this that depend on conditions of human embodiment and capacities (see e.g. Piaget and Inhelder, 1956; Grosz, 1995; Gibson, 1986; Holanda, 2017); or, much more simply expressed: it is reasonable that on a very basic level, walls 'always' matter, and they matter not only as material boundaries, but because they are extended socio-spatial material communicative actions.

It is worth noting that in a similar sense, *modelling* operates related to subjectivities and relations of self-to-environment and thereby integrates, in a certain sense, aesthetical questions by default. Here, there is arguably a somewhat uneasy analogous relation between model and architecture. While analytic models can move towards reducing non-discursive aesthetic influences, this very incorporation of aesthetics also forms one of the theoretical bases for the necessity to understand that any model (of architecture) contains a certain integration of aesthetics, which is part in what necessitates adaption of modelling principles after architectural cultures; as the model is always already influenced by an aesthetic position in terms of disposition and mode of subjectivity, it needs to be related to the architecture analysed towards a similar model-work relation in compared cases.

7. ECOLOGIES OF MODELLING

If we insist on looking at the question as one of ecologies—be it in the terms of Gibson's (1986) affordances or Guattari's (2000) three ecologies—one might come closer to a resolution by *accepting* that modelling is dependent on inquiry not from a practical perspective or as a result of empirical practice, but from a theoretical perspective. If affordances are related to cognition (Gibson 1986), cognition depends on purpose (Tversky, 2003), and perception of what constitutes a boundary is aesthetically and culturally conditioned, then the model used must depend on investigative purpose. If these models then respond to different relational ecologies, one can begin to structure theories around not only which models correspond to which ecologies, but *how ostensibly similar models need be understood differently for different ecologies*. I.e., a 'convex space map' to read co-presence as basis for interaction, might need be different from a 'convex space map' that describes socio-spatial organization not only from a practical perspective but from a cognitive-interpretative perspective in how space is understood by inhabitants for different purposes even though they in a particular instance may coincide. Similarly, it is possible that there are several versions of axial- and isovist maps that are 'correct' within a larger number of versions that are 'incorrect'. This is arguably known in research practice but not made explicit in a theoretically robust manner. Rather, one might criticize theorizations of models to instead insist on *one* explanation even when analytical practice deviates therefrom. This theoretical position suggests, however, a necessity to revisit analytical models and thoroughly engage with their principles to see just how they respond to which *types* of purposes.

From this position, one might consider models of spatial configuration to be part of research theory and practice in the sense Ekaterina Svetlova (2015, p.70) describes: "models are epistemic artifacts or tools that are purposely created for particular practical goals and are *made* productive by means of human intervention and manipulation within particular scientific practices. The definition of models as epistemic tools situates them as material objects that are not 'ready-made' but rather unfolding elements of situational practices." If these epistemic tools, as Downes (2011) notes, hold a ternary relationship with modeler, theory, and 'the world' (where 'the world' is often twice remote via different forms of data) and serve to both mediate and transform in-between, then it is not only possible but reasonable to consider a range of *specific* models (of space) to differently approximate the theoretical position and the investigated object or phenomenon while remaining within the same 'theory-model-space'. Sugden (2000) further discusses such kinds of relations through the concept of *robustness*; that is, models have robust relations if they provide, in principle, the same results as one another within bounds set by the research inquiry, a concept that can be extended to the relation between theoretical 'ideal' and specific model. One reason for this is the necessity of every model to be specific *in ways* the theoretical query or investigated phenomenon might not be—but also that the transformations enacted in these unfolding situational practices might be what allows knowledge discovery to begin with (Châtelet, 2000). This is not meant to disqualify research into the specifics and precision of particular models, but to suggest the more precise this investigation gets the more it might limit the model's generic validity, and that within the wider research premise of relations between spatial configurations and social, cultural, economic, experiential or other phenomena, the challenge is not to find the universally 'true' model, but to identify ranges of validity and relevance of the different models employed, including their mode of defining spatial limitations (not only concerning e.g. axial versus convex maps, but also e.g. axial maps considering pedestrian paths boundaries and axial maps not considering the same), and the theoretical grounds on which they stand as well as what queries they might respond to. This is where continuous refinement is needed, and where this article operates. *Accepting* that analysis making use of spatial units that deviate from specific definitions is relevant, but *insisting* that these units need to find a theoretical basis in how they are constructed that operates not only on an overall theoretical level, but on the level of detail in which the units themselves are deployed.

8. CONCLUDING WORDS

The argument put forth in this article is that it is only by accepting that there is a plurality of models within the shared basis of material-spatial configuration that knowledge can be further developed. It is also by accepting that the theoretical formulation has a specific relation to the various models and the models have a particular relation to 'reality' that the theoretical groundwork can be refined. From such a position one might then continue to refine models to better respond to different knowledge challenges and different architectures, while incorporating such development into the strategic research challenges of syntactic research as formulated in *The Social Logic of Space*. One might also investigate what sort of models—and not only measures—turn out as more widely relevant, for which problem spaces they are so and for which problem spaces the specific choices in their creation become obscuring or hindering. And, following Sugden (2000), in what situations different models have *robust* relations to one another and to theoretical basis in relation to research query. It builds theory that includes diversity where there may be models that have more generic relevance while other models are more explanatory for specific research questions. This then becomes an important point of theorization and empirical inquiry to further develop. Such a position requires theoretical advancement of what the models are, but also of where we would find breaking points where the proxy becomes invalid by virtue of deviating too far from that which one intends to investigate. This is not a question of simply whether it provides correlations or not, but of whether *the correlations (or non-correlations) provide answers to the research question at hand, and whether these correlations can be ascribed to the properties which one purports to investigate the influence of or relation in-between.*

The argument does suggest, however, that there are important questions regarding not only 'space', but the differentiation and definition of space into units for graph analysis—and the relation between space and boundary—that needs further investigation, where operations on existing models or by means of different measures on the same will not provide answers. It also suggests that such research needs to again approach the uneasy relation between configuration and geometry and engage with *what geometries* should affect such differentiation, in what situations, under what circumstances, and for what purposes. It further suggests that releasing the models from a state as being absolute, there

are possibilities to more solidly engage with different models as proxies of both one another and of theoretical or principal research inquiries.

But it also points to that there are fundamental theoretical differences between models, that may make use of one type for research into certain challenges more or less *invalid*, while the most appropriate for research into other challenges. The question of 'for what purpose' is put at the forefront *with its theoretical foundation*, just as the situated context of the model *as related to the research inquiry.* As stated initially, this article does not presume to resolve all of these questions and provide a singular theoretical solution; the intention is rather to draw out a theoretical problem space and examine directions through which unresolved modelling and analytic questions might come to be resolved, while at least suggesting how they could be as well as what remains to be researched in order to do that.

ACKNOWLEDGEMENTS

This paper has been researched and written within the project C-ARC at Chalmers University of Technology, funded by the university.

REFERENCES

Alexander, Christopher. (1964). *Notes on the Synthesis of Form.* Cambridge, MA: Harvard University Press.

Aragüez, Marcela and Sophia Psarra. (2017). Spatial and social patterns of an urban interior – The Architecture of SANAA. *The Journal of Space Syntax* 7(2), p.193-218.

Bafna, Sonit. (2005). Symbolic content in the emergence of the Miesian free plan. *The Journal of Architecture* 10(2), p.181-200.

Ballantyne, Andrew. (2011). Architecture, Life, and Habit. *The Journal of Aesthetics and Art Criticism* 69(1), p.43-49.

Benedikt, Michael L. (1979). To take hold of space: isovists and isovist fields. *Environment and Planning B: Planning and Design* 6, p.47-65.

Berghauser Pont, Meta, Gianna Stavroulaki, Jorge Gil, Lars Marcus, Miguel Serra, Birgit Hausleitner, Jesper Olsson, Ehsan Abshirini and Ashley Dhanani. (2017). 'Quantitative comparison of cities: Distribution of street and building types based on density and centrality measures'. In *Proceedings of the 11th International Space Syntax Symposium,* ed. Teresa Heitor, Miguel Serra, João Pinelo Silva, Maria Bacharel, and Luisa Cannas da Silva, Lisbon: Instituto Superior Técnico, p.44.1-18

Biondolilo, Matthew J. and Davud B. Pillemer. (2015). Using Memories to Motivate Future Behaviour: An experimental exercise intervention. *Memory* 23(3), p.390-402.

Butler, Judith. (1999). *Gender Troube: Feminism and the Subversion of Identity.* London: Routledge. (orig. 1990).

Butler, Judith. (2005). *Giving an Account of Oneself.* New York: Fordham University Press.

Châtelet, G. (2000). *Figuring Space: Philosophy, mathematics, and physics*. Trans. R. Shore & M. Zagha. Dordrecht: Kluwer.

Dalton, Ruth Conroy. (2005). Space Syntax and Spatial Cognition. *World Architecture* 11 2005, p.107-111.

Dalton, Ruth Conroy and Sonit Bafna. (2003). The syntactical image of the city: A reciprocal definition of spatial elements and spatial syntaxes. In *Proceedings to the 4th International Space Syntax Symposium*, ed. Julienne Hanson, London: Space Syntax Laboratory, p.59.1-22.

Dougherty J. W. D. (1978). Salience and Relativity in Classification. *American Ethnologist* 5(1), p.66-80.

Dovey, Kim. (2008). *Framing Places: Mediating power in built form.* 2nd ed. New York: Routledge. (Orig. 1999)

Downes, Stephen M. (2011). Scientific Models. *Philosophy Compass* 6, p.757-764.

Emmons, Paul. (2006). Embodying networks: Bubble diagrams and the image of modern organicism. *The Journal of Architecture*, 11(4), p.441-461.

Emo, Beatrix. (2017). Exploring isovists - the egocentric perspective. In *Proceedings of the 10th International Space Syntax Symposium,* ed. Kayvan Karimi, Laura Vaughan, Kerstin Sailer, Garyfalia Palaiologou, and Tom Bolton , London: UCL, p.121.1-8

Figueiredo, Lucas. (2015). 'A unified graph model for line and segment maps'. In *Proceedings of the 10th International Space Syntax Symposium*, ed. Kayvan Karimi, Laura Vaughan, Kerstin Sailer, Garyfalia Palaiologou and Tom Bolton, London: UCL, p.146:1–146:11.

Forty, Adrian. (2000). *Words and Buildings: A vocabulary of modern architecture*. New York: Thames & Hudson

Foucault, Michel. (1982). Space, Knowledge, Power; interview with Paul Rabinow. Trans. Christian Hubert, *Skyline*, March 1982.

Gibson, James. (1986). *The Ecological Approach to Visual Perception*. London: Lawrence Erbalum Associates.

Giuliani, Maria Vittoria. (1987). Naming the rooms: Implications of a change in the home model. *Environment and Behavior* 19(2), p.180-203.

Godfrey-Smith, Peter. (2005). The Strategy of Model-Based Science. *Biology and Philosophy* 21(5), p.725-740.

Grosz, Elizabeth. (1995). *Space, Time and Perversion: Essays on the politics of bodies.* London: Routledge.

Guattari, Félix. (2000). *The Three Ecologies.* Trans. Ian Pindar and Paul Sutton. London: Athlone Press. (orig. *Les trois écologies*, Paris: Éditions Galilée, 1989).

Hanson, Julienne. (1998). *Decoding Homes and Houses*. Cambridge, UK: Cambridge University Press.

Hanson, Julienne and Bill Hillier. (1987). The architecture of community: Some new proposals on the social consequences of architectural planning decisions. *Architecture et Comportment/Architecture and Behavior* 3(3), p.251-273

Hillier, Bill. (1996). *Space is the Machine: A configurational theory of architecture*. Cambridge: Cambridge University Press.

Hillier, Bill. (2003). 'The architectures of seeing and going: Or, are cities shaped by bodies or minds? And is there a syntax of spatial cognition?' In *Proceedings to the 4th International Space Syntax Symposium*, ed. Julienne Hanson, London: Space Syntax Laboratory, p.6.1-6.6.34.

Hillier, Bill. (2012). Studying Cities to Learn about Minds: Some Possible Implications of Space Syntax for Spatial Cognition. *Environment and Planning B: Planning and Design* 39(1), p.12-32.

Hillier, Bill and Alan Penn. (2004). Rejoinder to Carlo Ratti. *Environment and Planning B: Planning and Design* 31, p.501-511.

Hillier, Bill and Julienne Hanson. (1984). *The Social Logic of Space.* Cambridge: Cambridge University Press.

Hillier, Bill and Shinichi Iida. (2005). Network Psychological Effects in Urban Movement. In *Lecture Notes in Computer Science* 3693, p.475-490.

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

Holanda, Frederico de. (2017). Urban Fissures. *The Journal of Space Syntax* 7(2), p.141-164.

Hwang, Yongha. (2013). 'Network Communities in the Visibility Graph: A new method for the discretization of space'. In *Proceedings of Ninth International Space Syntax Symposium*, ed. Young Ook Kim, Hoon Tae Park, Kyung Wook Seo, Seoul: Sejong University Press, p.045:1-13.

Jiang, Bin and Christophe Claramunt. (2004). Topological Analysis of Urban Street Networks. *Environment and Planning B: Planning and Design* 31(1), p.151–162.

Kant, Immanuel. (1974). *Critique of judgement.* Trans. J. H. Bernard. New York: Hafner Press.

Kaye, Nick. (2000). *Site Specific Art: Performance, place and documentation.* Taylor & Francis, London.

Klein, Alexander. (1927). 'Versuch eines Graphischen Verfahrens zur Bewertung von Kleinwohnungsgrundrissen' [An attempt at a graphical procedure for evaluation of small scale apartment plans]. *Wasmuths Monatshefte für Baukunst und Städtebau* 11, p.296-298.

Knoespel, Kenneth. (1999). 'Models and diagrams within the cognitive field'. In *Model-Based Reasoning in Scientific Discovery,* ed. Lorenzo Magnani, Nancy J. Nersessian and Paul Thagard, New York: Kluwer Academic, p.59-73.

Knoespel, Kenneth. (2002). Diagrammatic transformation of architectural space. *Philosophica* 70, p.11-36

Koch, Daniel. (2005). 'Parallel Spatial Scales: discerning cognitive levels of space'. In *Proceedings to the 5th International Space Syntax Symposium, Volume II,* ed. Akkelies van Nes, Delft: Techne Press, p.373-386.

Koch, Daniel. (2007). *Structuring Fashion: Department stores as situating spatial practice*. Stockholm: Axl Books.

Koch, Daniel. (2012). 'Isovists Revisited: Egocentric space, allocentric space,and the logic of the Mannequin'. In *Proceedings: Eighth International Space Syntax Symposium,* ed. Margareta Greene, José Reyes & Andrea Castro, Santiago: PUC, p.8144:1-23.

Koch, Daniel. (2017a). Memory, Projection, and Imagination: On challenges to observations and statistics based research. *Contour 2: Agents/Agency of Urbanity*, p.1-15.

Koch, Daniel. (2017b). 'On Aesthetics and Spatial Configuration'. In *Proceedings of the 10th International Space Syntax Symposium*, ed. Kayvan Karimi, Laura Vaughan, Kerstin Sailer, Garyfalia Palaiologou and Tom Bolton, London: UCL, p.162:1-14.

Krippendorff, Klaus. (2006). *The Semantic Turn: A new foundation for design*. London: Taylor & Francis.

Leuder Christoph. (2017). Evaluator, Choreographer, Ideologue, Catalyst: The Disparate Reception Histories of Alexander Klein's Graphical Method. *Journal of the Society of Architectural Historians* 76(1), p.82-106.

Magnani, Lorenzo, Nancy J. Nersessian and Paul Thagard. (1999). *Model-Based Reasoning in Scientific Discovery.* New York: Kluwer Academic.

March, Lionel and Philip Steadman. (1971). *The geometry of environment: an introduction to spatial organization in design*, Hertford: Riba Publications Limited.

Marcus, Lars. (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, Lars and Daniel Koch. (2017). Cities as implements or facilities – The need for a spatial morphology in smart city systems. *Enviornment and Planning B: Urban Analytics and City Science* 44(2), p.204-226.

Marcus, Lars, Westin, Sara and Lasse Suonperä Liebst. (2013). Network buzz: Conception and geometry of networks in geography, architecture and sociology. In *Proceedings of the 8th international space syntax symposium,* ed. Young Ook Kim, Hoon Tae Park and Kyung Wook Seo, Seoul: Sejong University, p.068.1–13.

Markus, Thomas A. (1993). *Buildings & Power: Freedom and control in the origins of modern building types*. London: Routledge.

Marshall, Stephen, Jorge Gil, Karl Kropf, Martin Tomko and Lucas Figueiredo. (2018). Street Network Studies: from Networks to Models and their Representations. *Networks and Spatial Economics* [Online].

McCarty, Willard. (2008) 'Modeling: A study in words and meanings'. In *A Companion to Digital Humanities,* ed. Susan Shreibman, Ray Siemens and John Unsworth, Oxford: Blackwell, p.254-270.

Miranda, Pablo and Daniel Koch. (2013). 'A Computational Method for Generating Convex Maps Using the Medial Axis Transform'. In *Proceedings of Ninth International Space Syntax Symposium*, ed. Young Ook Kim, Hoon Tae Park, Kyung Wook Seo, Seoul: Sejong University Press, p.064:1-11.

Montello, David R. (2007). The Contribution of Space Syntax to a Comprehensive Theory of Environmental Psychology. In *Proceedings to the 6th International Space Syntax Symposium Volume I,* ed. Ayse Sema Kubat, Özhan Ertekin, Yasemin İnce Güney, Engin Eyüboğlou, Istanbul: ITU Faculty of Architecture, p.iv.1-12.

Morello, Eugenio and Carlo Ratti (2009). A Digital Image of the City: 3D Isovists in Lynch's Urban Analysis. *Environment and Planning B: Planning and Design* 36(5), p.837–853.

Penn, Alan. (2003). Space Syntax and Spatial Cognition: Or Why the Axial Line? *Environment and behavior* 35(1), p.30-65

Penn Alan, Ruth Conroy, Nick Dalton, Laura Dekker, Chrion Mottram, Alasdair Turner. (1997). 'Intelligent Architecture: New Tools for Three Dimensional Analysis of Space and Built Form'. Paper presented at the Proceedings, First International Symposium on Space Syntax, London

Peponis, John. (1985). The Spatial Culture of Factories. *Human Relations* 38(4), p.357-390.

Peponis, John. (2005). 'Formulation'. *The Journal of Architecture* 10(2), p.119-133

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

Peponis, John. (2017). On the Pedagogical Function of the City: a morphology of adolescence in Athens, 1967-1973. *Journal of Space Syntax* 7(2), p.219-251.

Peponis, John, Jean Wineman, Mahmud Rashid, S. Hong Kim and Sonit Bafna. (1997). On the Description of Shape and Spatial Configuration inside Buildings: Convex Partitions and Their Local Properties. *Environment and Planning B: Planning and Design* 24(5), p.761-81.

Peponis, John, Jean Wineman, Mahmud Rashid, Sonit Bafna and S. Hong Kim. (1998). Describing Plan Configuration According to the Covisibility of Surfaces. *Environment and Planning B: Planning and Design* 25(5), p.693–708.

Peponis, John, Sonit Bafna and Zhongyu Zhang. (2008). The connectivity of streets: reach and directional distance. *Environment and Planning B: Planning and Design* 35, p.881-901.

Piaget, Jean and Bärbel Inhelder. (1956). *The Child's Conception of Space.* London: Routledge & K. Paul. (orig. *La Représentation de L'Espace chez l'Enfant,* Paris : Presses Universitaires De France, 1948).

Portugali, Juval. (2011). *Complexity, Cognition and the City.* Dordrecht: Springer.

Psarra, Sophia. (2009). *Architecture and Narrative: The Formation of Space and Cultural Meaning*. London: Routledge.

Psarra, Sophia. (2010). The Ghost of 'Conceived Space. *The Journal of Space Syntax* 1(1), p.17-29.

Raisis Vasilis. (1999). 'Expansion and Justification of Models: the Exemplary Case of Galileo Galilei'. In *Model-Based Reasoning in Scientific Discovery,* ed. Lorenzo Magnani, Nancy J. Nersessian and Paul Thagard, Boston: Springer, p.149-164.

Ratti, Carlo. (2004). Space Syntax: Some Inconsistencies. *Environment and Planning B: Planning and Design* 31, p.487-499.

Richter Kai-Florian, Stephan Winter and Sigit Santosa. (2011). Hierarchical Representation of Indoor Spaces. *Environment and Planning B: Planning and Design* 38(6), p.1052-1070.

Seamon, David. (2015). Understanding place holistically: Cities, synergistic relationality, and space syntax. *The Journal of Space Syntax* 6(1), p.19-33.

Shashank Bhatia, Stephan K. Chalup and Michael J. Ostwald. (2013). Wayfinding: a method for the empirical evaluation of structural saliency using 3D Isovists. *Architectural Science Review* 56(3), p.220-231.

Stavroulaki, Gianna, Lars Marcus, Meta Berghauser Pont and Leonard Nilsson. (2017). 'Representations of street networks in space syntax: towards flexible maps and multiple graphs.' In *Proceedings of the 11th Space Syntax Symposium,* ed. Teresa Heitor, Miguel Serra, João Pinelo Silva, Maria Bacharel, and Luisa Cannas da Silva, Lisbon: Instituto Superior Técnico, p.174.1–174.16.

Sugden, Robert. (2000). Credible Worlds: The status of theoretical models in economics. *Journal of Economic Methodology* 7(1), p.1-31.

Surtees, Andrew, Ian Apperly and Dana Samson. (2013). Similarities and differences in visual and spatial perspective-taking processes. *Cognition* 129(2), p.426-438.

Svetlova, Ekaterina. (2015). 'Modeling as a Case for the Empirical Philosophy of Science: The Benefits and Challenges of Qualitative Methods'. In *Empirical Philosophy of Science: Introducing Qualitative Methods into Philosophy of Science*, ed. Susan Wagenknecht, Nancy J. Nersessian and Hanne Andersen, Xham: Springer International, p.65-82.

Tafuri, Manfredo. (2000 [1968]). 'Toward a critique of architectural ideology'. In *Architecture Theory Since 1968,* ed. K. Michael Hays, Cambridge, MA: MIT Press, p.6-35.

Turner, Alasdair. (2003). Analysing the visual dynamics of spatial morphology. *Environment and Planning B: Planning and Design* 30(5), p.657-676.

Turner, Alasdair. (2005). 'Could a road-centre line be an axial line in disguise?' In *Proceedings of the 5th International Symposium on Space Syntax*, Delft: Techne Press, p.145-159.

Turner, Alasdair. (2009). 'Stitching Together the Fabric of Space and Society: An Investigation into the Linkage of the Local to Regional Continuum'. In Proceedings of the 7th International Space Syntax Symposium, ed. Daniel Koch, Lars Marcus and Jesper Steen, Stockholm: KTH, p.116.1-116.12.

Tversky, Barbara. (2003). Structures of Mental Spaces: How People Think About Space. *Environment and Behavior* 35(1), p.66-80.

Varoudis, Tasos and Sophia Psarra. (2014). Beyond two dimensions: Architecture through three-dimensional visibility graph analysis. *The Journal of Space Syntax* 5(1), p.91-108.

Wigley, Mark. (1995). *White Walls, Designer Dresses: The Fashion of Modern Architecture*. Cambridge: MIT Press.

Wölfflin, Heinrich. (1950 [1932]). *Principles of Art History: The Problem of the Development of Style in Later Art*. Mineola, NY: Dover Publications.

citing information

(see further http://www.12sssbeijing.com)
Koch, Daniel (2019) "Architectural Articulation and Configurations of Space: Advancing theory, principles and bases for spatial modelling", in *Proceedings of the 12th Space Syntax Symposium*, Beijing: Beijing Jiaotong University, p. 264-1:1-264-1:17.