XXVIII International Seminar on Urban Form
ISUF2021: URBAN FORM AND THE SUSTAINABLE AND PROSPEROUS CITIES
29th June – 3rd July 2021, Glasgow

City Information Modelling (CIM) - Morphological conceptualizations and digitizing urban design practices

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Abstract

Digital ubiquity brings revelations of emerging smart cities. However, planners and urban designers remain resistant to digitalization trends and remain devoted to traditional sketching and hand drawing. A major problem in digitizing planning and urban design practices is the misfit with current software. Urban designers need to deliver engaging illustrations of future cities, master plans or design guidelines. Facing a choice between Geographic Information Systems (GIS), Computer Aided Design (CAD), Building Information Modelling (BIM) or 3D modelling software, urban designers often sketch and draw over printed two-dimensional cadastral maps that derive from GIS. To address the lack of appropriate software for planners and urban designers, we are developing a new City Information Modelling (CIM) software in coordination with a wide group of urban morphologists and designers. This paper presents the initial developments of the CIM app as a digital tool focusing on urban design and morphological theories as an inspiration for programming. The CIM software will integrate GIS data that stores cadastral maps and creates a digital drawing board for urban designers and other actors in the urban planning and development processes. Bringing digital tools closers to practices of urban designers and other actors and stakeholders in the planning and development of cities will contribute to increase digitalization, but also inspiring new ways to discuss morphological theory in urban design practices, or operational urban morphology and morphologically informed urban design.

Keyword: *City Information Modelling (CIM), urban morphology, urban design, planning, digitalization*

Introduction

Digital ubiquity brings revelations of emerging smart cities encouraging transformations in architecture, planning and urban design (Duarte and Ratti, 2021). However, planners and urban designers remain reluctant to digitalization trends and remain devoted to traditional hand sketching and drawing. A major problem in digitizing planning and design practices is the misfit with current software. Urban designers need to deliver engaging illustrations of cities, master plans or design guidelines. Facing a choice between Geographic Information Systems (GIS), Computer Aided Design (CAD), Building Information Modelling (BIM) or 3D modelling software, urban designers often sketch and draw over printed two-dimensional cadastral maps that derive from GIS.

To address the misfit between the software for planners and urban designers and urban design practices, we are developing a new City Information Modelling (CIM) software through the coordination of a wide group of urban morphologists and designers. CIM will integrate with GIS which stores cadastral maps. The CIM software a will create a digital drawing board for urban designers and enable customized toolboxes to analyse and design cities for various actors and stakeholders. This paper presents the initial developments of the CIM app as digital tool focusing on urban design and morphological theories as inspiration for programming. It identifies actors and stakeholders in urban planning and development and positions urban designers in the process of developing and planning cities. It conceptualizes urban design elements based on theories for generic morphological structure (Conzen, 1960; Moudon, 1994; 1997; Kropf, 1996; 2009; 2011; 2014; 2018; Scheer, 2010; 2016; Stojanovski, 2019) to develop digital drawing boards for urban designers and various actors and stakeholders in the planning and development of cities. In conclusion, the paper presents glimpses into the new software, its drawing boards and discusses its future development.

Background

The background presents key concepts about digitalization and digitizing of urban design, morphological conceptualizations and City Information Modelling (CIM). *Digitization* is the conversion of analogue to digital, whereas *digitalization* is the use of digital technologies and digitized data to transform practices. Urban design can be defined as the art of making and shaping townscapes by creating compositions of elements in space (Taylor, 1999; Marshall, 2016). Urban designers have the unique background to deal with the experiential qualities of cities (Southworth, 2016). Designing cities is not an artistic undertaking towards an ideal (Talen and Ellis, 2004; Marshall, 2016). A city is the result of the interaction over often long periods by many actors and stakeholders, all with their own sets of values, interests and objectives. The cities are continuously under development. The first section reviews the literature and draws on morphological theories to presents resolutions and the structure of design elements. A subsection examines the actors and stakeholders in urban planning and development as potential users for the CIM software.

Morphological conceptualization for City Information Modelling (CIM)

In the literature, City Information Modelling (CIM) is predominantly conceived as an information model that derives from GIS and generative design inspired by the shape grammars of George Stiny (1980; e.g. Beirao and Duarte, 2005; Beirao et al., 2008; 2010; 2012; Gil et al., 2010; 2011; Duarte et al., 2012; Gil, 2020). CIM alternatively is conceived as **a** morphological aid for urban designers (Stojanovski, 2013; 2018; Stojanovski et al., 2020). The urban morphologists have conceptualized a structure of cities: streets, lots and buildings and their related open spaces (Conzen 1960; Moudon, 1997; Scheer, 2010; 2016; Kropf, 2011; 2018). Karl Kropf (2011; 2018) combined these conceptualisations into a generic morphological structure (Figure 1A).

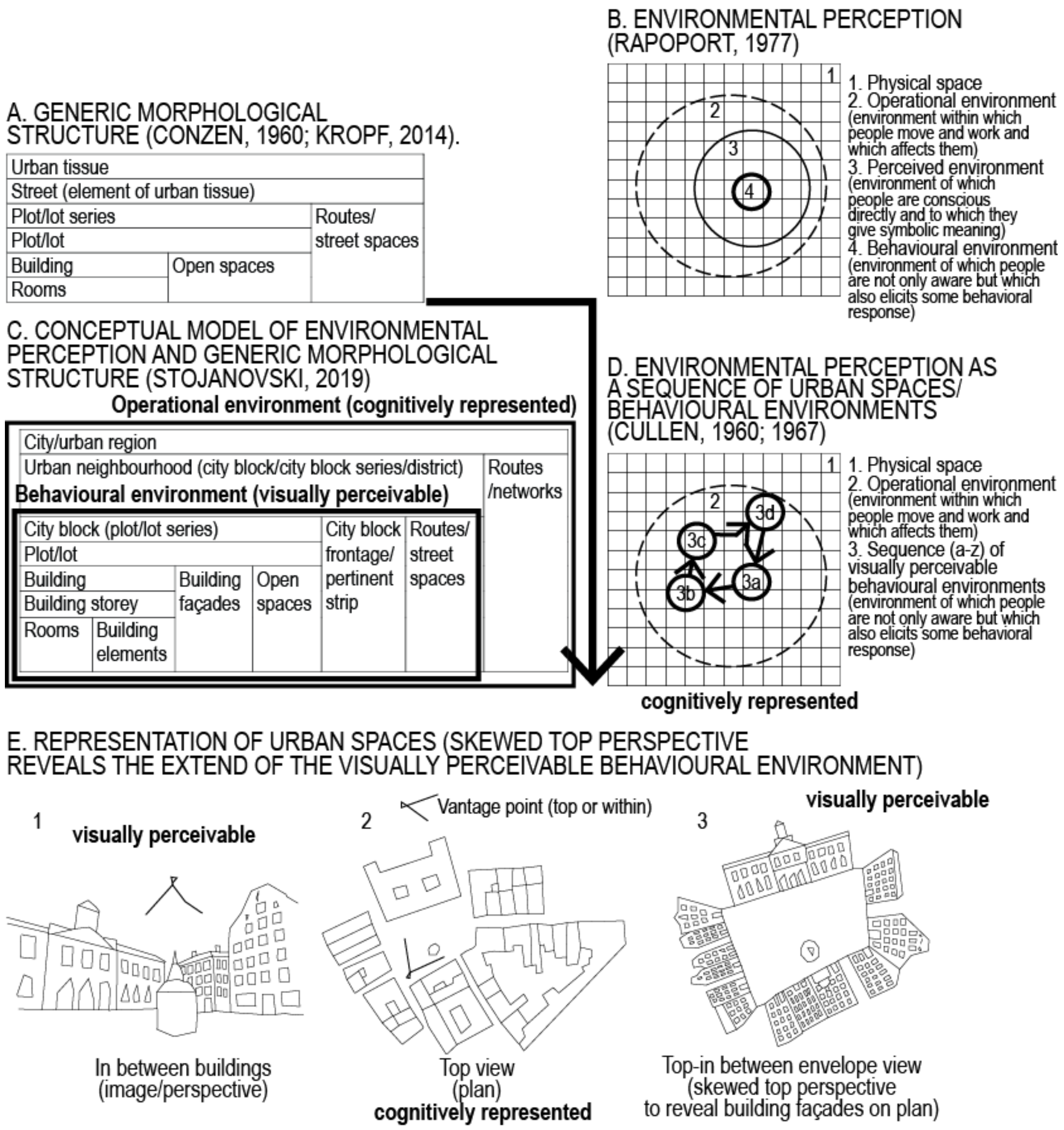

Figure 1. Understanding generic morphological structure (Conzen, 1960; Kropf, 2014) and environmental perception (Cullen, 1960; 1967; Rappoport, 1977; Stojanovski, 2019). Urban designers work with environmental perception and urban experience as visually perceivable images or the urban envelope.

Based upon psychological research on environmental perception, the generic morphological structure was modified to include streetscapes (Figure 4C). Jane Jacobs (1960) consider**s** the interaction between the street and building as an important morphological element (Caniggia & Maffei, 2001 [1979]; Kropf, 2011; also discuss differences in orientation of the building façades in the city block in respect to the routes). Environmental psychologists recognize layers of nested environments. The operational environment defines the space where people move and work. It is a movement space. The perceptual environment is the space where people are directly conscious and to which they give symbolic meaning. In the behavioural environment, people are not only aware but also perform behavioural response**s** (Rapoport, 1977). Figure 4B show**s** the perceptual hierarchy of environments. The visual experience includes a sequence of viewpoints (described as serial vision in Cullen, 1960; 1967) as centres of behavioural environments. The route as a sequence of viewpoints is the element of urban flow that becomes fixed in urban space (Figure 4D).

The diagrammatic knowledge and expressions of urban designers often implies transforming 3-dimensional spaces into 2-dimensional symbolic representations. Kevin Lynch (1960) created mental maps with urban elements that are perceived in cities. Gordon Cullen (1961; 1967) devised notations and symbologies of indicators describing viewpoints and experience of urban space. Urban designers in practice commonly combine theories and representations to create design toolboxes (e.g. Bentley et al., 1985; Walters, 2007). This hierarchical morphological structure can be analysed from the top or as street spaces, plots and buildings that are oriented and scaled to the street (Caniggia & Maffei, 2001 [1979]). Figure 1E proposes a urban envelope of streetscape model that involving a skewed 3D perspective. This 'envelope view' of urban space allows for the analysis of elements in street space and architectural elements on the building façade.

Actors and stakeholders in urban development

Cities are continuously under development. They developed incrementally at various resolutions from the upgrade of buildings and redesign of streets to large scale developments as new neighbourhoods and towns. There are many actors and stakeholders, all with their own sets of values, interests and objectives who shape the cities though interaction. The urban designers have a specific role in a broader process of planning and development of cities. Sue McGlynn (1993) developed a "Powergram" (Table 1) that broadly maps the power, responsibilities and interests of various planning and development actors in a context of the elements of the built environment (or morphological structure of cities, see Conzen, 1960; Moudon, 1994; 1997; Kropf, 1996; 2001; 2009; 2011; 2014; 2018; Scheer, 2010; 2016; Stojanovski, 2019). This hierarchical morphological structure can be analysed from the top as city blocks bounded by streets or as street spaces, plots and buildings that are oriented to the street emphasizing street-building interactions (Caniggia & Maffei, 2001 [1979]). Table 1 expands from McGlynn's "Powergram" with new elements for streets, public spaces and open spaces and landscape.

Table 1. "Powergram" of planning and urban design (expanded from McGlynn, 1993)

	FUNDER	FUNDER/PRODUCER		PRODUCERS										USERS	
Actor	**Investor**	**Developer**	**Landowner**	**Local authority**					**Professionals**					**General public**	**Civic society**
Elements of the built environment				**Local politician**	**Strategic planer**	**Detailed planer**	**Traffic engineer**	**Mobility manager**	**Architect**	**Urban designer**	**Landscape architect**	**Planning consultant**	**Placemaking consultant**		
Streets:	-	-	-	●	o	o	●	●	-	o	o	o	-	o	o
-layout design	-	-	-	●	o	o	●	-	-	-	-	o	-	o	o
-section design	-	-	-	-	-	o	●	-	-	-	o	o	-	-	-o
-circulation	-	-	-	●	-	-	●	●	-	-	-	-	-	o	o
-parking	-	-	-	●	o	o	●	●	-	o	-	o	-	o	o
Streetscapes: -frontages	-	-	o	o	-	o	-	-	o	o	-	-	-	o	o
City blocks:	-	-	-	●	●	●	-	-	-	o	o	o	-	-	-
Lots: -subdivision & amalgamation	●	●	●	●	●	●	-	-	-	+	o	o	-	-	-
-land use	●	●	●	●	●	●	o	-	-	+	o	o	-	o	o
-parking	-	+	+	●	●	●	●	-	o	+	-	o	-	o	o
Buildings: -height & mass	●	●	●	●	●	●	-	-	+	+	-	o	-	o	o
-building use	●	●	●	●	●	●	o	-	+	+	-	-	-		
-elevations & façade design	-	●	●	o	o	o	-	-	+	o		-	-	o	o
-elements of construction	-	●	●	-	-	-	-	-	+	-	-	-	-	o	o
-orientation to public space	-	-	-	o	o	o	-	-	-	o	-	o	-	o	o
Public spaces	-	-	-	●	●	●	o	o	-	o	o	o	+	o	o
Open spaces & landscape:	-	-	-	●	●	●	o	o	-	o	+	o	o		

● POWER – either to initiate or control
\+ RESPOSIBILITY – legislative or contractual
o INTEREST/INFLUENCE – by argument or participation only
\- No obvious interest

The “Powergram” was modified to include the new professions such as mobility managers and placemaking consultants that emerged in the last three decades. The municipal planners are also differentiated according to topics of interests. Strategic planners have a broader perspective on planning trends, technological development and sustainability concerns. They tend to envision and initiate new ideas that are discussed with politicians and citizens and are turned into policy goals and strategical documents. The detailed planners turn strategical documents into master plans. The master plans are usually legally law binding and serve as legislation to obtain a building permit (in Sweden developers draw up master plans in coordination with municipalities to cut costs). The mobility manager is a new profession inspired by the paradigm for sustainable mobility (Cervero, 1996; Marshall & Banister, 2000; Marshall, 2001; Banister, 2008) that has a broader perspective on transportation. Like the strategical planners, the mobility managers work with policy goals and strategic documents and they initiate various projects to affect circulation and parking. However, they do not interfere in infrastructural decisions about streets and transportation that are traditionally left to the traffic engineers. The various actors see the city from their own viewpoints at different resolutions. The power to influence the urban development, their responsibilities and interests are summarized on Table 1.

The urban designers are either professionals or they are employed in the municipalities as detailed planners. Urban designers have a specific role to envision and illustrate cities as input into urban planning and development processes. Urban design practices range from delivering neighborhood designs and master plans with conventional two-dimensional zoning to writing design codes and building ordinances (on Form-Based Codes or FBCs, see Walters, 2007). Urban designers reflect upon the social context and morphology of cities to create new visions for future buildings and cities (Figure 3). The concept of design worlds describes the process of designing. The design worlds are environments inhabited by designers when designing. Design worlds act as holding environments for diagrammatic design knowledge (Schön, 1988) where urban design and morphology are entangled (Samuels, 1999; 2008; Marshall and Caliskan, 2011; Marshall, 2012).

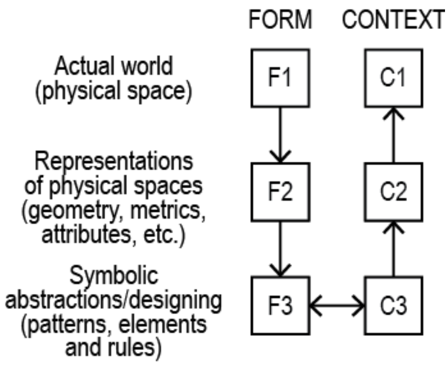

Figure 3. *Understanding the design process/abstractions of the city (Alexander, 1973 [1964], p.76). Urban designers work with experiential qualities of cities and symbolic abstractions by creating compositions of design elements in urban space. The symbologies and toolboxes of design elements vary from designer to designer and from city to city.*

Designing in City Information Modelling (CIM)

The City Information Modelling (CIM) software is designed with an interface that will enable actors that have the power and responsibility to create compositions of morphological elements of urban form, streets, lots and buildings and their aggregations, into city blocks. Landowners, developers, investors and municipal planners focus on lots and zoning (including land and building uses) as development zones, traffic engineers have the power to layout roads and transform street spaces, whereas architects have contractual responsibility for the design of buildings. Urban designers work with the experiential qualities of cities (Southworth, 2016) emphasizing the interaction between streets (and other public spaces) and the buildings located on the lots, particularly the aggregation of lots into city blocks that influence~~s~~ urban qualities. The initial CIM software is programmed for developers (who seek~~s~~ development opportunities on the cadastral map), urban designers (who deal with experiential qualities by creating a smooth interaction between streets and buildings), traffic engineers (who work with designing streets and roads) and citizens/civic society (as consumers and users), but in long term we aim to make customized toolboxes for all the actors and stakeholders.

Figure 3 shows the elements and operators in the development of a CIM interface for the Developer interface. The developers (including investors, landowners, and municipal planners) see the city as a mosaic of lots with and without buildings which have a development potential. The developers work with two operators. They can split a lot and create a new lot or merge several lots to create a larger development. Figure 4 shows the lot as development tile with number of urbanist parameters regulated by building ordinances or urban codes.

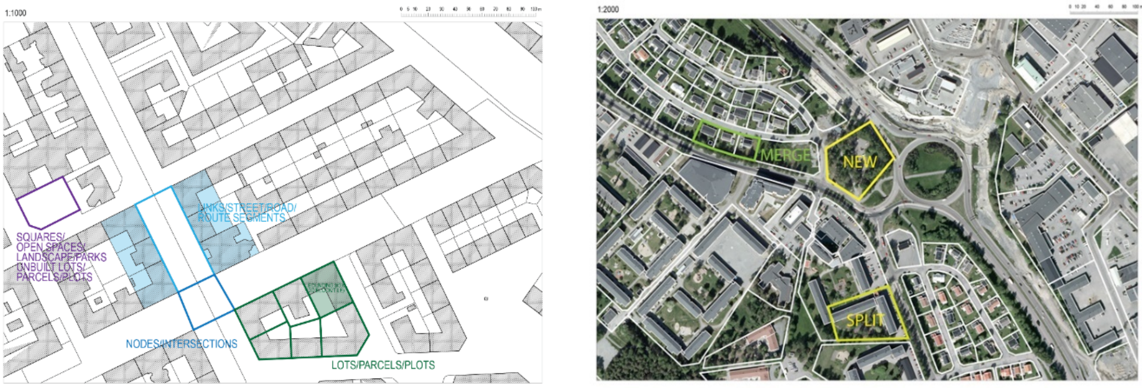

Figure 3. *Developer interface and operators in CIM. A) the city is divided in lots with buildings, streets (including street segments/links and intersections/nodes as lots) and lots without buildings (squares, parks, greenery, landscape, etc.). The developers work with two operators. They can split a lot and create a new lot or merge several lots to create a larger development.*

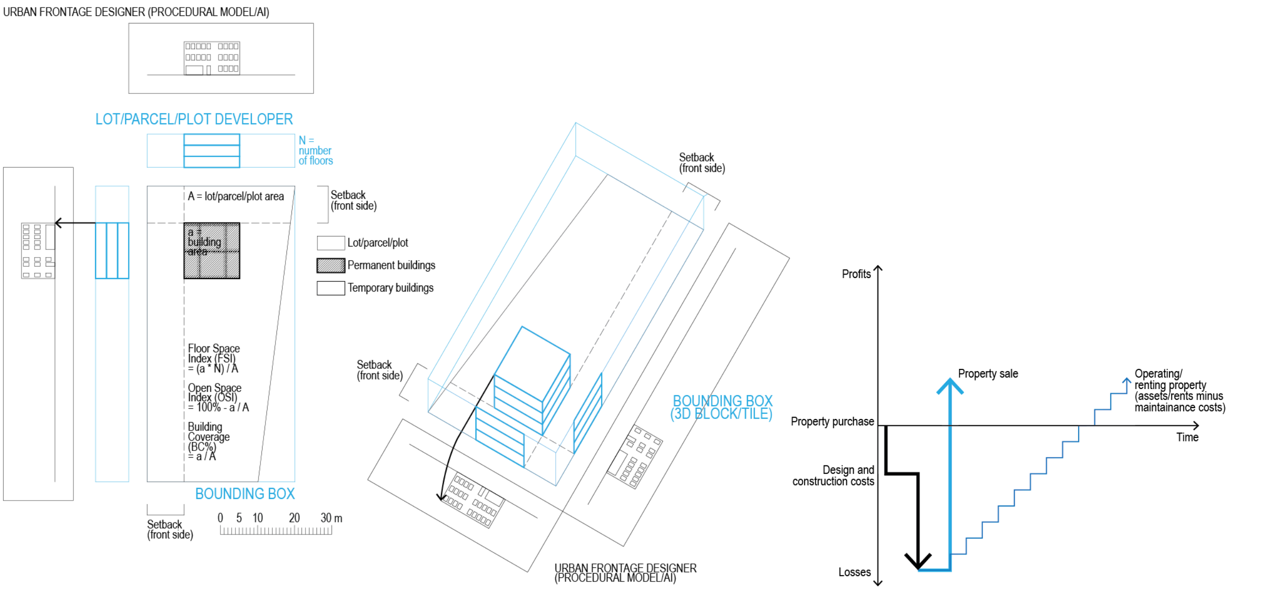

Figure 4. *Development metabolism of the lot as **a** piece of land. The development of the lot is regulated by urban design coefficients, building ordinances or urban codes that determine the maximum size of allowed development. Knowing these restrictions, the developers purchase or lease property in order to construct new buildings and quickly sell them or operate the buildings over number of years and earn profits.*

The second interface in CIM involves digitization of the practices of urban designers and traffic engineers. Urban designers focus on the interaction between streets and the buildings, particularly the aggregation of lots into city blocks that influences urban qualities. Figure 5 shows the street design practices and Figure 6 the morphological conceptualization behind the development of Streetscaper/Townscaper interface that will allow urban designers and traffic engineers to design streets spaces (Figure 3 above illustrates the lots/parcels under streets as nodes/intersections and links/street segments). Figure 5A1 and Figure 5B1 show differences in definition of the city block. The definition in Figure 5A1 matters for urban developers who aim to buy and merge lots/parcels to create a larger development zone - the city block shown as the aggregation of all the lots/parcels is the maximum. Figure 5B1 emphasize an urban designer perspective to understand street space in three dimensions as interaction of the street and buildings (as advocated by

Jacobs, 1961; Caniggia & Maffei, 2001 [1979]). This definition allows the representation of the elements of street spaces (Figure 5B2) including transportation models in the street section (Figure 5B2) and the gradual development of an envelope view of street space with building façades (Figure 5B3 and Figure 5B4). This transformation of three-dimensional space into a planar projection will allow urban designers and traffic engineers to design streets spaces. Figure 7A shows the design toolbox for links/streets/roads/route segments where it is possible to change building heights and land uses of buildings on the lot and select transportation modes that will circulate in streets. Figure 7B illustrates the design toolbox for nodes that includes transportation modes.

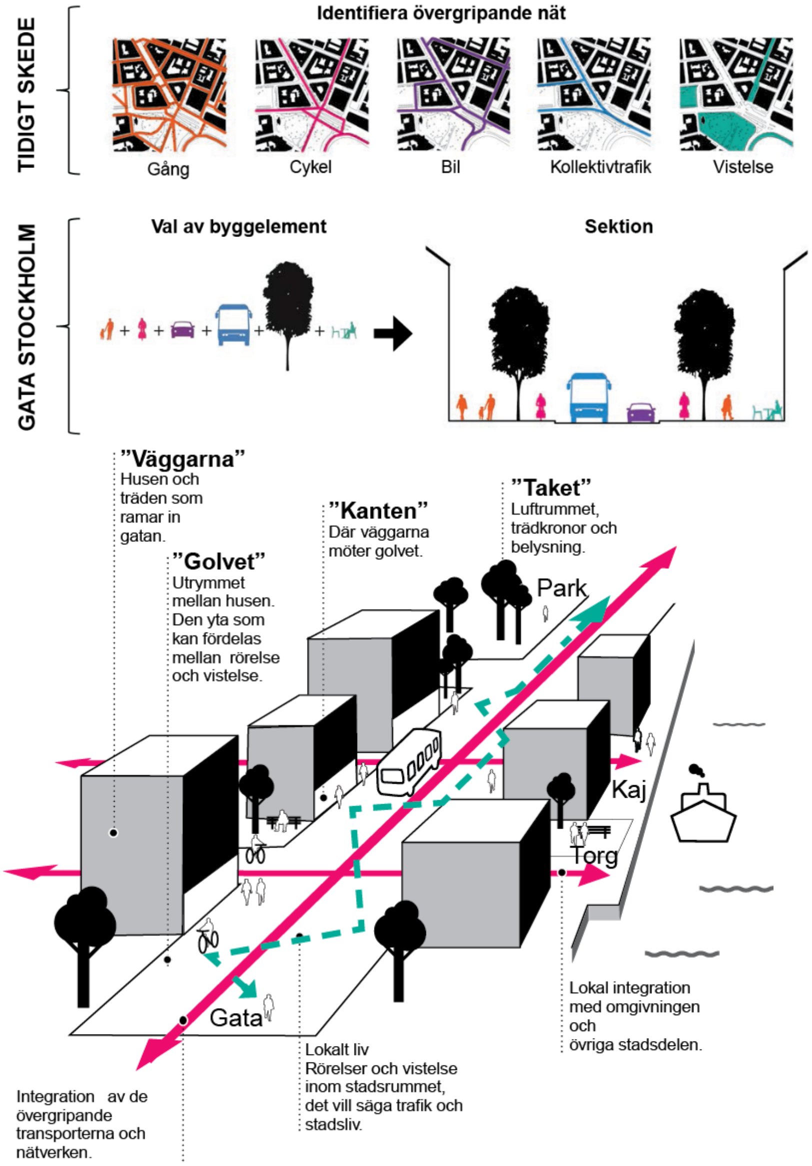

Figure 5. *Stockholm municipality works with streetspaces/towscapes by identifing goals for multimodal transportation as networks for walking, cycling, private car, public transportation and public spaces (squares and main promenades) and designing street sections to grasp streetspaces/towscapes in 3D. (The manual Gata Stockholm is available on: https://tillstand.stockholm/globalassets/foretag-och-organisationer/tillstand-och-regler/tillstand-regler-och-tillsyn/lokal-och-fastigheter/handbocker-och-riktlinjer-vid-byggnation-i-stockholm/gata-stockholm.pdf)*

Figure 6. *Morphological conceptualization behind Streetscaper/Townscaper interface that will allow urban designers and traffic engineers to design streets spaces.*

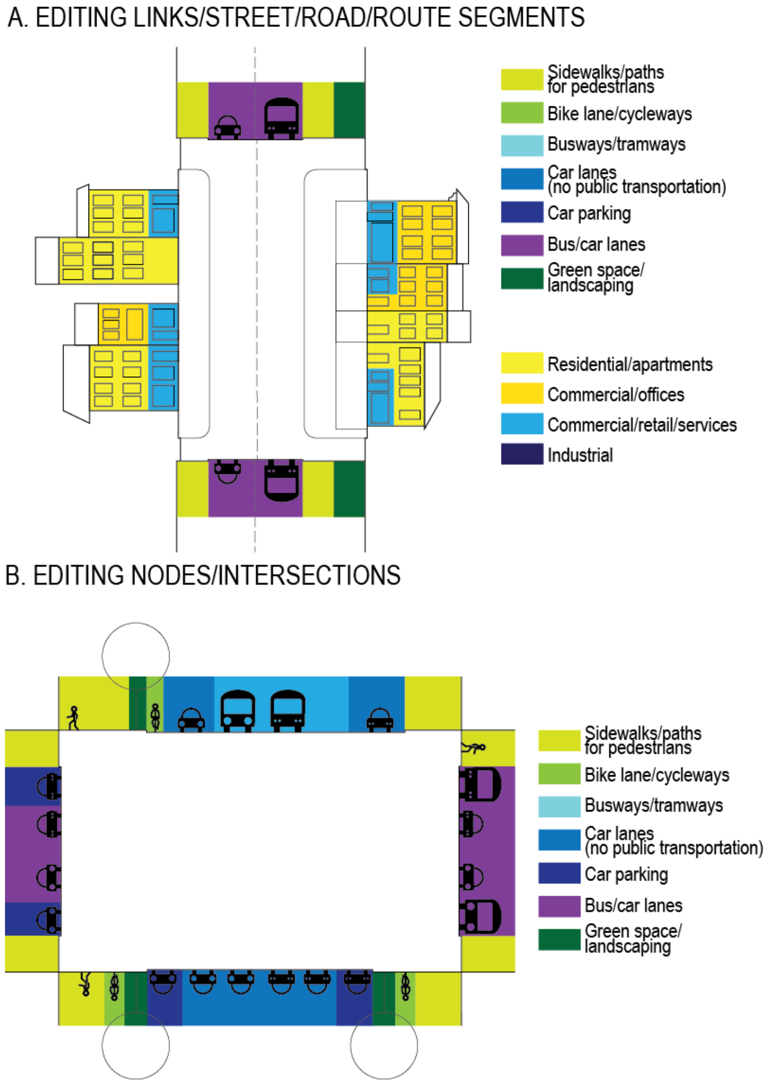

Figure 7. *Streetscaper/Townscaper interface that will allow urban designers and traffic engineers to design streets as spaces. A) shows the design toolbox for links/streets/roads/route segments where it is possible to change building heights and land uses of buildings on the lot and select transportation modes that will circulate* ***in*** *streets. B) illustrates the design toolbox for nodes that includes transportation modes.*

Discussions and conclusions

This paper presents morphological conceptualization about CIM and urban design theory about actors and stakholders that are programmed in a digital tool (as add-on to the open-source GIS software QGIS). Figure 8 shows a preview of the CIM software that is under development. The CIM software will start with selecting a role in the planning and development process and it will show the Developer and Urban Designer/Streetscaper/Townscaper interfaces (that is still not implemented fully). The conceptualizations of actors and stakeholders is an upgrade of McGlynn's (1993) "Powergram" (Table 1) that maps the power, responsibilities and interests of various planning and develop actors and stakeholders in a context of the elements of the built environment. It is applied in a context of Western and Northern European planning practices. The planning processes and urban development vary across countries, but the morphological conceptualizations can have a broader application as the generic structure of cities.

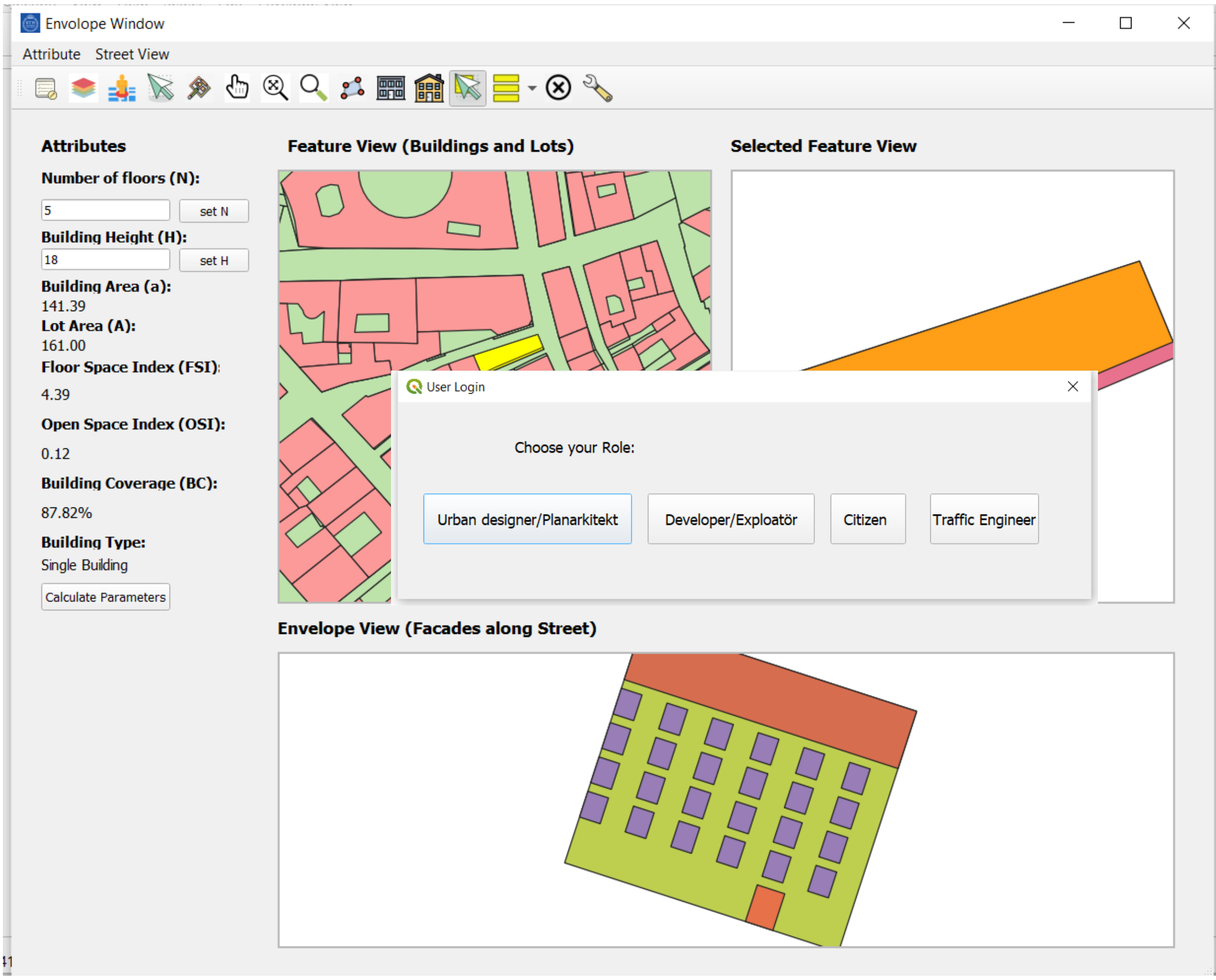

Figure 7. *A preview of the CIM software (as addon in QGIS) that is under development starting with users and showing the Developer and Urban Designer/Townspacer/Streetcaper (that is still not implemented fully)* *[Figure caption]*

The CIM software aims to fully integrate not only the generic morphological structure of cities and various analytics from notations and symbologies (Lynch, 1960; Cullen, 1961; 1967; Bentley et al., 1985) and sustainability assessments (in a context of transportation see Stojanovski 2019b; 2019c; 2020a). The CIM software will be used to develop future scenarios and alternative urban designs. In the long term it will also incorporate algorithms that will automatically deliver engaging illustrations of cities, master plans or design guidelines (including building ordinances and FBCs, Walters, 2007). The CIM software will create a set of digital drawing boards for urban designers. Bringing digital tools closers to the practices of professional urban designers will contribute to increase the digitalization of planning and inclusion actors and stakeholders in the urban planning and development processes, but also to inspire new ways to discuss morphological theory in relation to urban design practices, or operational urban morphology and morphologically informed urban design.

Acknowledgements

The authors of this paper gratefully acknowledge the grants P44455-1 and P44455-2 from the Swedish Energy Agency, Energimyndigheten, that sponsor the development of CIM software and sustainable transportation assesments.

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