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Digital Information Tools for Urban Regeneration: Capital's Approach in Theory and Practice

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Abstract: Urban regeneration, which includes renovation of decaying urban structures as well as renovation of dilapidated buildings, is an important economic, aesthetic and cultural factor for sustainable development planning worldwide. The revitalization of urban structures is a complex challenge, influenced by various interdisciplinary aspects, like urban socio-economic development, integrated transport and mobility solutions and others. And it requires involvement of different stakeholders at different levels in identifying and finding solutions. Technological innovations offer a variety of digital tools to address modern urban governance and modelling issues, identifying problem areas with public involvement and participation that allow relevant services to respond quickly, thus improving the urban environment and the quality of life of people. With the help of digital tools, it is also possible to promote the availability of public services, model and forecast environmental risks, as well as perform other functions integral to the organization and management of modern society. However, the wide range of these tools and their mutually asynchronous use often make it difficult to choose the right tool, thus creating the risk of fragmented implementation. The aim of this paper is to propose theoretical approach for modelling of complex interactions affecting urban regeneration as well as summarize and systematize the existing digital information tools which might empower the process of regeneration. The analysis of the use and impact of digital and smart tools allows to identify urban problems, as well as to outline ways to solve them. The results of the research will form the basis for further research stages.

Keywords: urban regeneration; digital tools; smart city

1. Introduction

Urban regeneration, which includes recovery of degraded buildings and neighborhoods, renewal of decaying structures and brownfield development is a challenge of many cities around the world. Moreover, urban regeneration process also affects variety of crosscutting issues such as challenges of transport and mobility, public services, urban development and planning, and integral socioeconomic development [1,2]. In our digital age, modern technologies and tools are playing an increasingly important role in urban regeneration processes.

Technological innovation offers variety of digital and smart tools to address the challenges of contemporary urban governance, supporting citizen participation, improving the urban environment and so the quality of life, supporting production and management of public services, enabling modelling and prediction and deal with environmental risks. However, wide range of these tools

makes the choice to use certain approaches more difficult and so leads to fragmented implementation. The above-mentioned processes could be seen as a part of wide and complex phenomena's as Digital City and Smart City. Digital City could be described as a free trend emerging from the daily use of smart and digital devices by citizens, and it incites the local governments to supply e-services, that is, to gradually transform the city into a Digital City [3]. Open data plays a significant role here. Moreover, the Digital City gradually becomes the Smart City that denotes the effective integration of physical, digital and human systems in the built environment to deliver a sustainable, prosperous and inclusive future for its citizens [4].

There is a variety of implementation focused researches in the field of urban regeneration, information systems and smart technologies [5]. So, for example, in 2016 started the REPLICATE project, which aims development of an innovative business model which supports use of innovative technologies in co-creation of the built environment. The My Smart City District aims sharing knowledge on the energy efficient renovation and large-scale replicability of solutions. The project partners from Sharing Cities are working on solutions for more efficient use of energy, low carbon transport and buildings. Variety of different actions were tested in terms of mySMARTLife project. Activities are tackling the issues of inclusive cities, smart people and smart economy. E-mobility, lighting and smart meters, energy data lab in Nantes, smart street light and concept of "smart heating islands" in terms of the retrofitting project in Hamburg, as well as Helsinki urban platform, the 3D city data and IoT platforms which used to guide refurbishment activities, all these are just few examples from the actions taken within mySMARTLife. However, the spread of solutions and fragmented approaches face the lack of common framework.

This paper aims to propose a certain unifying theoretical approach to a process of urban regeneration and systematize approaches and tools used in terms of urban regeneration and up-to-date information systems. The focus is located on community involvement in the process of identification, management and maintenance of the problematic sites and buildings as well as overview of online digital tools and mobile applications helping people to get orientated in the city life and public services. The role of different actors in urban regeneration using digital tools will be analyzed on the experience of Riga.

2. Methodological Approach: Interacting Capitals

City is a complex system where various social, cultural, economic, ecological and other processes interact constantly with and within urban space. Interaction between various processes could be seen as two-directional process: social, economic or other processes call for certain spatial configurations while space may either positively or negatively catalyse certain activities. Bill Hillier explains that such an interaction could be based on the principle of "movement economy" [6]. According to it, spaces with the best reachability attract certain people, functions and object which benefit from the good reachability (e.g., commercial object, street culture activities, etc.). New objects and activities, on their turn—attract even more people and objects thus utilising spatial potential further, etc. The principle of "movement economy" could be seen as one of the basic principles of self-organization of urban structure. Space Syntax, which is based on the movement economy principle, and employs mathematical graph model as its tool, might serve as an illustration of effectiveness of such a modelling approach while predicting allocation of city functions, understanding its spatial-social logic, etc. Lars Marcus utilized Space Syntax modelling potential while offering the terms "Spatial Capital" [7]. The idea is based on the "capital" concept which is used in economic and social studies. Marcus offered to see city as a system of interacting capitals: Spatial, Social, Economic and Ecological. The four capitals are defined in the following ways:

- "Spatial capital is a representation of spatial form that can be linked to social, economic and ecological processes in cities, thereby allowing them to be consciously directed by urban design" [7]. Based on Space Syntax approach the spatial urban configurations could be analysed in the terms of co-presence or symmetry, closeness, multifunctionality, etc.

- The idea of social capital, according to Marcus, is grounded on the studies of collective human activities where concepts of trust, cooperation and both formal and informal institutions are essential [8]. It is based on works of Robert Putnam, who defines social capital as the “Collective value of all social networks and the inclinations that arise from these networks to do things for each other” [9].
- Economic capital: “It is easy to see how the notion of cities as a landscape of co-presences of varying size and differentiation, in economic terms can be translated into a landscape of markets; what are economic markets but co-presences of people and things . . . We see the importance of transport costs in these models, something that may vary for many reasons, energy costs, degree of congestion and infrastructural standard. However, underpinning any such cost is physical distance, which is what routinely is structured and shaped by way of spatial form in urban design.” [7].
- According to Marcus “humans... are understood as an intrinsic part of nature and ecological process... We may illustrate (it) through the ecosystem service pollination. To facilitate such services in an urban area, we need to create support for both essential agents . . . functioning ecosystems are in spatial terms a set of locations linked together in a configuration that allow movement between them.” [7].

In order to reflect cultural dimensions of urban-social-spatial-economic ecosystem two more capitals could be added: cultural and symbolic.

In sociology and anthropology: “symbolic capital can be referred to as the resources available to an individual on the basis of honour, prestige or recognition, and serves as value that one holds within a culture.” [10].

Cultural capital is based on such personal but socially valuable and dependant assets as education, intellect, lifestyle, style of speech and dress, etc. Cultural capital “promote(s) social mobility in a stratified society” [11]. “Cultural capital functions as a social-relation within an economy of practices (system of exchange), and comprises all of the material and symbolic goods, without distinction, that society considers rare and worth seeking” [12]. Cultural capital is divided into embodied or inherited from culture, objectified (person’s property), institutionalized (e.g., recognized by institution qualifications).

In more detail, interactions between the capitals are summarized in urban terms in the Table 1.

The essential benefit of the proposed capital approach is a possibility to structure otherwise quite hard to model urban reality and, at least in the part of capitals use quantitative modelling tools. Could such a possibility be clearly demonstrated at least at hypothetical level?

Table 1. Generalized description of capitals and interactions between them in urban terms.

Economic Capital (EcC): Assets That Can Enhance One’s Power to Perform Economically Useful Work	
<ul style="list-style-type: none"> • Interaction with a city in general terms: • Relations to Spatial Capital (SpC): • Possible modelling approach: • Indicators: 	<p>market relations act as a background for economic functioning of a city; could be seen as force utilizing all other capitals in economic processes (including ScC)</p> <p>SpC creates added value by offering spatial conditions which allow successful economic functioning</p> <p>a monetary or exchange-value</p> <p>monetary value or costs</p>
Social Capital (ScC): Collective Value of Social Networks. Two Types of ScC: Bridging and Bonding	
<ul style="list-style-type: none"> • Interaction with a city in general terms: • Relations to Spatial Capital (SpC): • Possible modelling approach: • Indicators: 	<p>creates in general direct background of society; might be increased by an attachment to a specific place/location</p> <p>SpC catalyses co-presence</p> <p>social network description, socio-top map [13], etc.</p> <p>number of social connections</p>
Ecological (Natural) Capital (EnC): Environmental Resources; Value of Relations with Environment Created by Functioning of Ecosystems	
<ul style="list-style-type: none"> • Interaction with a city in general terms: • Relations to Spatial Capital (SpC): • Possible modelling approach: • Indicators: 	<p>movement of energy, materials and information is conducted on the base of physical infrastructure (including spatial configuration)</p> <p>SpC creates conditions for ecosystem services in terms of various flows (materials, energy, information)</p> <p>functional potential of ecosystems</p> <p>diversity and connections (openness) of eco-subsystems or biotopes</p>
Cultural Capital (ClcC): “ClcC Comprises the Social Assets of a Person (or Social Group) that Promote Social Mobility in a Stratified Society” [11]	
<ul style="list-style-type: none"> • Interaction with a city in general terms: • Relations to Spatial Capital (SpC): • Possible modelling approach: • Indicators: 	<p>it could be seen as closely related to ScC and EcC as an additional attribute layer; it might be utilizing certain spatial locations for its demonstration</p> <p>SpC affects ClcC by using spatial configuration as a tool to reflect and create ClcC through reflecting some cultural space usage scenarios</p> <p>modified socio-top mapping [13]; semantic structure</p> <p>patterns of ClcC features (might be spatially mapped)</p>
Symbolic capital (SyC): “Resources Available to an Individual (or Society) on the Basis of Honour, Prestige or Recognition, and Serves as Value That One Holds within a Culture”—Semantic Cultural Symbols	
<ul style="list-style-type: none"> • Interaction with a city in general terms: • Relations to Spatial Capital (SpC): • Possible modelling approach: • Indicators: 	<p>it could be seen as closely related to ScC and EcC as an additional attribute layer; it might be utilizing certain spatial locations for its demonstration</p> <p>SpC could be affected by the objects related to or holding SyC as catalysers of SpC; SpC, on its turn, can make the objects of SyC more or less intelligible in a city</p> <p>semantic structure</p> <p>pairs of oppositions describing semantic structure</p>
Spatial capital (SpC): Value Created by Spatial Configurations for Both Functional Needs and Urban Resilience	
<ul style="list-style-type: none"> • Interaction with a city in general terms: • Possible modelling approach: • Indicators: 	<p>provides/creates conditions for functioning of all other capitals by creating conditions for spatial movement of people</p> <p>quantitative models of spatial configurations which might be related to qualitative aspects; it is important to say that so called bottom up or complex models are essential here as they have a power of predictability and imitate real processes if comparing to descriptive, top-down models</p> <p>mathematical graph based model and calculated centralities; agent-based model, Cellular Automata model, Fractal index</p>

Spatial capital concept, as it was mentioned earlier is based on space syntax theory and empirically tested methodology which, on its turn, looks at a city as a network of interrelated elements. Mathematical graph model is employed as a tool to describe network in quantitative way. Mathematical graph is made of two elements: nodes and edges or links between nodes. Depending on the field of investigations, modelled object and detail level of analysis, different network elements could be seen as nodes, e.g.: humans in social network, street crossroads in logistic network, territorial units in a city, etc. The essential mathematical operation in graph model is calculation of centrality of importance of the node. At least three, the most common centrality types described the first time by Freeman [14,15] could be mentioned here:

- Degree centrality as a number of edges of each node. Higher degree centrality might mean bigger number of social contacts of a person or bigger number of visual connections with neighbouring spaces in an urban square
- Closeness centrality as a sum of distances from selected node to all the other nodes of a network. The lowest value of closeness centrality means that the precise node is in the most reachable position in a network
- Betweenness centrality as a number of the hypothetical shortest journeys between all possible pairs of nodes which cross a node for which calculation is made. A higher number might mean bigger flows of information, materials, or energy in a network. This type of centrality is the most often used for transport flow modelling in a city while street crossroads are seen as network nodes

Space syntax employs centrality calculations as a basis for urban network analysis with one significant shift—focus on urban and/or architectural space as a container of social processes. It is reflected by specific approach to node description. In contrast to already mentioned identification of crossroads as nodes in transport flow modelling (so called primary approach) space syntax sees street spaces and segments between crossroads as nodes (so called secondary approach). The argument in favour for the secondary approach might be that street life is the most often happening in its space defined by surrounded buildings but not crossroads which are more important in logistic terms. Additionally, space syntax is offering more graph types besides axial and segment ones which as well follow space-container principle, e.g.: Convex graph where a whole visually integral space is seen as a node or visual graph when space is tessellated into equal cells and each cell seen as a node. In all graphs used by space syntax rules for edge (link between nodes) creation are similar—it is either possible to move from one node to another one directly or it is possible to move from one node to another one without change of movement direction based on visibility. These graphs in essence could be expanded by adding buildings as important elements of interface of public spaces to them thus even increasing versatility of syntactic approach. As a result of space syntax modelling received indicators demonstrate functional potential or “capital” of elements of investigated urban structure in various terms, e.g.: Reachability which might be related to higher intensity of territory or space use and multi-functionality; attraction for either pedestrian or transport flows; higher connectivity between spaces as indicator of more intensive street culture, etc. In generalization it could be pointed out that the syntax based on graph model belongs to the group of so called bottom up models together with agent based modelling and cellular automata, which have a predictive power and allow not only to describe phenomena of reality, but discover regularities of its functioning, so, in a case of application to a city, it helps to understand how spatial configurations are affecting sociocultural processes and space usage scenarios and might affect them in a future.

Could a mathematical graph approach be used effectively for quantitative description and predictive or bottom-up modelling for other types of the capitals? Could it be combined with spatial capital decryptions in order to model synergies between capitals? Can the model reflect phenomena of augmented reality which could be seen as related to Digital City and Smart City? Can up to date information systems help to create and present such models?

Evidence for applicability of graph model for social capital could be based on two statements. The first one: social capital is described as connections between people which form a network. Secondly—already referred works of Freeman [14,15] developed three indexes of centrality while analysing social networks. Hypothetically the most detailed social network graph should be made of people as nodes with various relations represented as edges, but, creation of such a model, at least at the present situation, would be not very much realistic task at a scale of a city or its bigger part. How might graph of social capital look in real situation based on the real available data? It could be based on three initial principles:

- Humans are territorial beings, so a node of the graph could be seen as a territorially integrated, homogenous group of people
- Similar social status, education level, age, etc. might increase probability of social connections
- Physical neighbouring of human groups and territories increase probability of social contacts

Such information is available as census data in many counties, e.g., Lithuanian census data from 2011 represents a number of inhabitants, age, sex, education, occupations, income level, nationality for equally sized cells of territory while a size of the smallest cell is 100 on 100 meters in cities. According to the above described three principles, a social graph might be formed according to the following rules:

- One 100 × 100 m cell represents one node of the graph while number of inhabitants represent a weight of a node
- Node-cell is connected with the neighbouring nodes-cells if they have a common border—the same principle is earlier mentioned convex graphs offered by Space Syntax theory
- Node is connected with distant nodes if both represent the same dominant social groups

The model created on the described rules should be validated and calibrated by comparing to real situation and the rules could be updated and expanded depending on the validation results, but in essence it offers as simple as possible hypothetical approach which is based on logic of deduction and abductions, and is testable in an inductive way (e.g., sociological survey). The Digital City and Augmented reality phenomena could be reflected in the social capital graph by adding connection rules based on participation in social networks or similar platforms. Various data sharing platforms could be used to collect, or check data needed for the graph.

Ecological capital by Lars Marcus is related to various services of ecosystem. The general ecosystem model described it as a set or network of interconnected elements which function together because of flows of materials, energy, and information. Ecological approach could be very wide and encompass both human made and natural elements, but in essence the basic simple principles for the ecological capital creation could be described as following:

- All elements or species and services of ecosystem could be associated with certain territory
- Higher diversity of elements/services and interactions between them could be seen as indicator of higher ecological potential or capital. It could be grounded by general statement that more diverse system has more possibilities to adapt to changing conditions
- Closeness of elements make the interaction more probable

Ecological capital graph, depending on actuality of services in a particular city (e.g., recreational services, support of diversity of local flora and fauna, etc.) could be created in a similar approach as social graph:

- Territory could be divided into equal cells (e.g., 100 × 100 m)
- Neighbouring cells/nodes are connected with each other in two cases depending on selected ecological services: if they have a common border; if a distance between them fall within certain actual range, e.g., daily travel distance of an actual specie or size of its biotope

- Distant nodes/cells could be connected on the base of existing ecological corridors. In a case of recreational services, it would be green connections, pedestrian alleys, bicycle routs; in a case of biotopes—corridors of journeys of various species

Weight of the nodes could be related to various indexes showing ecological potential of a territory. If the presented above focus on nature services is taken in ecological capital graph, then various digital tools can play a significant or even essential role in crowd data collection and its sharing.

Economical capital by Lars Marcus is related to journey costs and service areas and it is related to money values employed to either goods, services, or territories. As additional prove of this statement and a background for clarification of essential graph creation principles and rules a hedonistic land price concept could be mentioned. It means that closeness of certain objects or territories to, let's say, living house or flat, affects its price in either positive or negative way [16]. If the territoriality of economic activities in a city is still taken as an axiom even in an age of development of IT technologies, then principles for economic capital graph creation could be established as following:

- Various commercial activities might support each other and benefit from closeness to each other
- Commercial activities benefit from closeness to public functions and infrastructural services which attract more people
- Each commercial activity has its service area
- Commercial and public services might catalyse each other in both positive and negative ways

The economic graph might be based on the following rules according to the above mentioned four principles:

- Territory could be divided into equal cells as it was offered for social and ecological graph. Each territorial cell becomes a node which might be weighted according available data on economic activities which could be related directly or indirectly to the number of customers, e.g.,: size of commercial area, generated income, number of employees, type of activities, etc. Such data, in a case of Lithuania, is available for 100 × 100 m territorial cells
- Neighbouring cells could be connected depending on positive catalysation and service area distance. Both aspects could be evaluated on the base of sociological survey
- Distant cells could be connected on the base of infrastructural connections as the main routes and public transport lines classified according to a journey speed including waiting time as stops

As it already mentioned, the part of needed data is already available, another part could be obtained via sociological surveys, count of movement flows or data crowding. Augmented reality aspect might be representable on the base of additional links in the graph based on social media or similar phenomenon, or reflected as node weights based on the type of activities (e.g., e-commerce) and generated income, but, having in mind a-locality of such phenomena, it should be treated with certain limitations.

Can digital and information technologies (DT/IT) affect how capitals are functioning and interacting or make the modelling task easier?

In the case of Economical Capital DT/IT technologies make all economic processes much more accessible and faster, e.g., IT platforms replace physical banks, e-money replace notes; time and physicals space for interaction is losing significance; etc.

In the case of Social Capital DT/IT technologies make all social processes much more accessible and faster; IT platforms partially replace physical contacts and enable distant participation in various social processes, including spatial planning; significance of physical space might be decreasing of, if access to augmented reality offered—increased (e.g., internet cafes of public spaces)—social capital network might affect network of physical spaces as a weight.

In the case of Ecological Capital DT/IT technologies help to optimize some services of anthropo-ecosystem (e.g., Energy and material flows, traffic flows, etc.); modify information flows (e.g., More actively forming conceptual perception of a city—city image, feeling of identity, etc.).

In the case of Cultural Capital DT/IT technologies create a new platform for creation/generation and disseminations/usage of cultural capital.

In the case of Symbolic Capital DT/IT technologies create new types texts (augmented reality, social networks) and symbols of cultural/social status and allow to share information about the owned old ones.

In the case of Spatial Capital DT/IT technologies modify interaction with physical environment (augmented reality phenomenon; apps and data which optimize interaction, etc.); allow collection of various data, its presentations and usage for analysis, modelling and prediction which was not possible earlier. The last aspects are of essential significant if speaking about the role of Spatial capital as catalyser of other capitals and enabler of resilience based on processes in the capitals.

As it was demonstrated in the description of examples of graphs of various capitals various available data or digital tools for its easier collection can be seen as a significant factor which makes implementation and testing etc. The mentioned available information could be relatively easily and reliably expanded while using of the proposed models significantly easier. Just few cases could be mentioned here: open street map for spatial capital modelling; census and commercial activity open data; data on urban greenery, data crowding IT tools and technologies. Usage of the same mathematical background and data in GIS format allows combination of capitals and, in a case of successful validation, modelling and prediction of interaction results between the capitals. The proposed model could be seen as a major expansions of Space Syntax traditional models.

How the capitals are related to urban regeneration? If relating to biology, “regeneration is the process of renewal, restoration, and growth that makes genomes, cells, organisms, and ecosystems resilient to natural fluctuations or events that cause disturbance or damage. Every species is capable of regeneration, from bacteria to humans” [17]. If this description will be applied to urban system, then it might mean that success of urban regeneration could be measured and modelled on the base of interaction and synergy between the capitals.

3. Results: Classification of DT/IT for Urban Regeneration

As the city is a complex and multi-layered system integrating not only physical structures but social, economic, ecological, cultural and spatial processes as well, the regeneration of degraded city areas which seeks optimal result from all the mentioned aspects needs to integrate multi-actor insights, knowledge and perspectives that are usually not considered within the formal planning process [18,19]. We consider that there are two factors important for the assurance of effective integration of knowledge and transdisciplinary nature of urban regeneration: capital’s approach and contemporary information systems and digital tools. Capital’s approach allows to use quantitative modelling tools based on digital data and to achieve synergy between top-down and bottom-up regeneration processes. There are six types of capitals that are covered by different digital tools which enables to evaluate different aspects of the particular capital (Table 2).

Table 2. Generalized description of capitals and interactions between them in urban terms.

No	DT/IT	Types of Capitals					
		Economic	Social	Ecologic	Cultural	Symbolic	Spatial
Urban and Regional Information Infrastructure (Data about All Social, Economic and Environmental Issues)							
1.	GIS	+	+	+	+	+	+
2.	RS	+	+	+			+
3.	Google maps	+	+	+			+
4.	OpenStreetMap	+	+	+			+
5.	Maps.lt	+	+	+			+
6.	Geoportal.lt	+		+	+		+
7.	Regia.lt	+		+			+
8.	Kvr.kpd.lt				+		+
9.	Tpdr.lt	+		+			+
10.	Tpdri.lt	+		+			+
11.	Zeldynai.mapika.lt			+			+
Digital Environmental Models (Information Organization and Analysis)							
12.	DEM, DSM, DTM	+		+			+
13.	Digital Twin	+		+	+		+
14.	CIM	+	+	+	+	+	+
15.	City Engine	+		+	+		+
16.	ArchiCad				+		+
17.	Traffic flow analysis application sisp.maps.arcgis.com	+			+		+
18.	Revit				+		+
19.	SketchUp				+		+
20.	Graphics editor (for ex., Illustrator, Photoshop, etc.)						+
Communication Platforms							
21.	Online participatory mapping (for ex., Maptionnaire, Carticpe, MinStad, etc.)	+	+	+	+	+	+
22.	Mind mapping software (for ex., Ayoa, etc.)					+	+
23.	Online sociological surveys (for ex., Survio, google forms, etc.)	+	+	+	+	+	+
24.	Collective design and planning (for ex., Betaville, etc.)		+		+		+
25.	Augmented reality	+	+	+	+	+	+
26.	Tangible table		+		+		+
27.	Multi-screen system		+		+		+
28.	Social networks (for ex., Facebook, Instagram, etc.)		+		+	+	+

The first group of digital tools and information systems includes urban and regional information infrastructure that encompasses the data about social, economic and environmental issues important to the process of urban regeneration as the material to be analysed in order to determine the limitations and potential of a particular area [19]. Geographic information systems (GIS) are the main tool for handling common database of spatial and non-spatial data, their analysis and modelling. GIS are designed to work with both descriptive (attribute) and spatially coordinated information. All this information in the GIS is stored in thematic (homogeneous spatial information) layers. The main functions of GIS are searching, collecting, storing, presenting, analysing, editing and visualizing spatial information. GIS because of huge various information storing and integration capacities represents economic, social, ecologic, cultural, symbolic and spatial capitals. Remote sensing (RS) technologies allow detecting and classification objects on Earth using satellite or aircraft-based sensor technologies and concerning the objects detected conclusions can be made about the economic activities, social, ecologic or spatial processes. Cultural and especially symbolic capitals are not easily detected from objects' spatial configuration and other physical characteristics. Google maps, OpenStreetMap are web mapping services, offering satellite imagery, aerial photography, street, built up and green areas maps, streets perspective views, real-time traffic conditions, route planning, etc. They can be edited by everybody, adding relevant information about objects of the Earth surface. Maps.lt is an interactive Lithuanian online map website providing data from state databases in Lithuania, created on the basis of ArcGIS software. It is based on digital maps, vector geodatabases and GIS technologies. The content and geography of the maps are constantly filled in and updated, and a three-dimensional map of Lithuania is developed. The only difference that maps.lt cannot be edited by everybody. These online maps provide us with information about the spatial capital that allows us deciding about the conditions for the development of economic, social and ecologic capitals. The other online databases, like geoportal.lt, regia.lt, kvr.kpd.lt, tpdr.lt, tpdris.lt, zeldynai.mapika.lt are thematic databases encompassing information about the spatial planning decisions, cultural heritage objects, vegetation and representing spatial, economic, ecologic and cultural capitals accordingly.

The second group of digital tools represents digital environmental models that are important for the organization of information and analysis in different stages of the regeneration process (preparatory stage: objectives and tasks of planning, programme of works, feasibility studies, forecasting and etc., present state analysis, development of regeneration strategies, environmental impact assessment, elaboration of proposals, etc.) [19]. There are Digital Elevation Models (DEM), Digital Surface Models (DSM), Digital Terrain Models (DTM) used in GIS. A DSM represents the natural and built features on the Earth's surface and is useful for the 3D modeling in urban planning. DEM is the Earth's surface model without vegetation and man-made structures especially useful in hydrology, pedology, land use planning. DTM like DEM characterizes the shape of the bare-earth terrain but represents distinctive terrain features much better [20]. According to their specificity the models are important for the representation of spatial, ecologic and economic capitals. Digital Twin is a digital copy of a living or non-living physical object, represents both the elements and their dynamics [21] and is directly related with spatial, economic, ecologic and cultural capitals. CIM is for the creating and demonstrating 3D city models where various types of data is available including open data, sensors, IoT and even social media [22]. It covers all types of capitals. City Engine is a 3D city modeling software for creating urban environment based on GIS data. As the model is based on the available GIS data it represents spatial, economic, ecologic and cultural capitals. Archicad, Revit and SketchUp are the softwares important for buildings 3D modeling, thus encompassing cultural and spatial capitals. Graphics editors are used for the creating and editing images and represents mainly the spatial capital. There is created traffic flow analysis application for Vilnius city that analyses the intensity of traffic flows and is directly related with ecologic and spatial capital having in mind that human-beings are a part of socio-ecosystem of the city and are responsible for its dynamic equilibrium.

The third group of digital tools is a communication platform that is the main instrument for the communication between the planners, decision makers and representatives of the interested

parties [19]. They can be more suitable for two-ways (exchange of information between experts and non-professionals on regeneration objectives, strategies, design proposals, and other types of information) or one-way (collection of information available to non-professionals that is necessary for experts to take the urban regeneration decisions) communication and are the most important for the development of social capital and assurance and stimulation of bottom-up urban regeneration processes. There are a lot of programs (Maptionnaire, Carticipe, MinStad, etc.) for online participatory mapping that includes the designating of important natural and man-made landmarks and public services, indicating of spatial features such as topography, greenery, water bodies, etc. Such maps may be drawn by a group of inhabitants and other stakeholders who are interested in the spatial formation issues of urban environment to be solved [23]. Online participatory mapping gives an opportunity to non-experts, who often have different and even conflicting interest, to communicate their ideas regarding the places and spaces. This tool enables local communities to express their wishes and point out challenges on the map, facilitate resource management, use their right to the city, and make the communication with planners easier [24]. Due to that it covers all types of capitals. Mind map is a graphic technique which transcribes an individual or collective subjective representation of space [25,26]. It represents how people experience space, forms of spatial intelligence and the dynamics of human-environment relationships [27] and is directly related with symbolic and spatial capital. Online mind-mapping software can be used for information organization and translation into the mind maps. Analysis of such maps can give planners valuable insights while planning the process of urban regeneration. Online sociological surveys are very popular platform of one-way communication between the planners and non-experts. As the online surveys are designed by planners, they can get various valuable information from non-experts on the topics they need and because of that this digital tool is relevant for all types of capitals. Online platforms of collective design and planning, tangible tables, multi-screen systems are a very valuable instrument allowing to create spatial living environment for non-experts and urban planners together starting from the house and ending up with the whole settlement influencing social, cultural and spatial capitals. Augmented reality can represent all types of capitals and is useful for the presentation of design solutions for non-experts to discuss them. Social networks are very important for the bottom-up regeneration of urban environment and thus for the development of social, cultural, symbolic and spatial capital.

While generalizing the theoretical research part it could be concluded that various digital tools (DT) can be used in different situation of urban regeneration. The presented preliminary descriptive matrix might be useful while evaluating availability of DT for a precise situation and construction of specific regeneration scenarios. Despite the big number of DT which enable understanding, analysis and modelling of the capitals, there is no simple, complex enough tool for this purpose. On the base of the idea of Marcus that the spatial capital is the most stable and has the highest degree of inertia in constantly changing urban system it might be proposed to make an attempt to model even more capitals on the base of mathematical graph approach. Such, at least partial, possibility could be confirmed by usability of graphs for networks and a network nature of social, ecological and some other capitals.

4. Case Study: A Digital Tool in Riga

Latvia shows problems with lack of cooperation in terms of urban regeneration and inefficient use of available digital information systems. There is a variety of urban environment data available online, however the content is very fragmented and target groups appear to be different. So, the city of Riga offers digital data on land-use, landownership, infrastructure development, public participation, and other issues, however data is spread across various platforms and often demands access request. Different platforms are created and lead by different actors, who don't cooperate and share knowledge. Certain amount of urban environment data is provided by various activity groups, NGOs and private organisations and makes the system even more fragmented. Place-making activities are becoming

increasingly popular in Latvia and so involvement of NGOs is crucial while developing urban regeneration scenarios.

The historic centre of Riga represents buildings of various centuries, with the oldest dating back to the end of the 15th century. For that reason, the maintenance of these building often appears a serious problem. Greater attention is usually paid to the maintenance of cultural monuments; Still, the buildings on the background and auxiliary buildings are facing challenges, as their aesthetic and technical condition often requires improvement. To monitor the technical and visual condition of the buildings and evaluate their impact on the quality of public open space of the city as well as to help the interested parties in their management, the Riga City Council in 2015 developed a digital platform <http://grausti.riga.lv/> with the support of the EU URBACT III project REFILL. Within five years of operation the platform has proved to work as effective tool to control the public involvement in the city management processes and supervise the quality of the environment.

The digital platform is focused at rising collaboration of community in the process of identifying and rearranging degraded buildings. The main goals to achieve are:

- to promote exchange of experience and ideas for the re-arrangement of degraded territories and degraded structures
- to share experience on the temporary use of empty buildings as an effective tool to prevent the emergence of slums and revitalize the degraded urban areas
- to create a sustainable platform of collaboration between Riga and other European cities [28].

The digital platform widely welcomes public activity in identifying the problematic properties. Since the opening of the platform in 2015 the number of re-arranged properties has significantly risen. If between the years of 2011 and 2014 there were fixed 70 re-arranged objects in average, only in the year of 2015 their number jumped to 141. Overall, at present, June 2020, 1209 facilities have been identified as problematic. Out of this number, 617 facilities are declared as environmentally degrading, 191 are appointed for further supervision, and 401 require further evaluation. Approximately 260 problematic sites are located in the territory of the historical centre of Riga, and about 230 in its protection zone [29].

To decide on the issues related to the identified problematic facilities, a special committee has been created. This committee was established at Property Department of the Riga City Council and it consists of 25 people: architects, officials and administrators of various municipal institutions in Riga and representatives from the non-governmental organizations. One of the main tasks is to organize and ensure the maintenance of the real estate, which is characterised with unsatisfactory technical condition or is badly influencing urban landscape. These measures may include demolition and other coercive measures if necessary. In 2019 the committee held 15 meetings. The digital platform is linked to topical international social networks—twitter, facebook, google, as well as to the local social network draugiem.lv, providing wide public access to the Riga city management issues [28].

Figure 1 explains the relation of grausti.riga.lv platform with the concept of capitals. This communication platform for urban regeneration mainly supports the social capital, by fostering social processes, exchange of ideas, fostering local and even international collaboration, community actions etc. Still, it is closely related to the other capitals. The platform makes the information on co-financing for urban regeneration more accessible, in this way supporting economic capital. Also, it shows some areas of potential investment. In relation to the spatial capital, platform offers GIS data, allows collection and analysis of spatial data, allows to see buildings as catalyzers of processes happening/might happening around them. For the cultural capital it allows to detect structures of cultural heritage that need renovation and regeneration actions. Symbolic capital is closely related to the cultural and social capitals. The ecological is not directly connected to the platform, still is indirectly influenced, as the approach we use to urban regeneration has consequences on ecological issues. The figure shows strong features and opportunities offered by the platform, at the same time pointing out the missing sectors, which might be developed to reach more integrative approach in urban regeneration. It is important to note that the existing Grausti.riga.lv platform with collected information

could be seen as a valuable source of data for the earlier discussed graph based mathematical modelling of the capitals and interaction between them, e.g.,: information about status of the buildings might be used for weighting of graph nodes in Spatial capital layer and analysis of its influence on the other layers of capitals; involvement of people into activities in the platform might serve as a good point for social capital modelling; etc.



Figure 1. Relevance of Grausti.riga.lv to capital's theoretical approach.

The comprehensive framework of urban regeneration tools referring up-to-date information systems gives not only significant theoretical data but also provides experimentally proved classification of parameters and “hidden” opportunities of digital tools, as the result, giving a basis for further development of applied solutions. The current effectiveness of the tools and creation of practical solutions addresses non-governmental organizations and stakeholders showing a variety of scenarios of urban regeneration, and so enabling them to choose and act more effectively.

5. Discussion

Although the range of DT involved in urban development is diverse in terms of both—objectives and technological solutions, three major groups can be identified by their role in urban regeneration.

Data collection, data analysis and modelling to determine the limitations and potential of a particular area; organization of information and analysis in different stages of the regeneration process; and communication between the planners, decision makers and representatives of the interested parties are the main areas of DT use in the process of urban regeneration.

New technologies offer an opportunity to introduce innovative solutions for public involvement in the actual processes of life, also in those of urban development. However, the innovator itself cannot control and sometimes is even unaware of all the impact factors which influence innovation. In case of radical innovation, uncertainty becomes the determining factor of the system's future [30]. The predictive models which see city as a complex system and make an attempt to reflect its bottom-up processes of self-organization might be very useful or even necessary in this situation.

A participatory approach is an organized process in which non-professionals—users, residents, visitors or stakeholders—work with planning and design professionals to create an open space in valuable sites. This process can have various directions: creatively design oriented, technically oriented

or management and policy oriented and bottom-up model supported oriented [28]. The participatory approach aims better understanding of a place and supports managers, experts, and users to offer innovative and effective design solutions. Variety of directions and actors, results in different and complex collaborative design practices. Goals change over time [31] and can be conflicting between and within people. As stated by Kaner et al., public participation builds the problem-solving skills of the community and enables them to deal with future challenges. But this statement is usually valid if the participants are driven by voluntary wishes, and are supported in their effort to contribute, have an opportunity to learn and develop new skills, can improve their competence, and have no fear of being requested to pay a fee for their involvement. For that reason, it takes time and active engagement to raise a collaborative mindset [32].

Experience with the communication platform aimed at monitoring the quality of public open spaces in Riga shows the great involvement and wish to participate by both the local community and city guests. By identifying the problematic sites, this communication tool allows the municipality to take the certain measures to facilitate their organization, thus improving the overall quality of public spaces.

6. Conclusions

The formal urban planning process is often unable to take into account the complex challenges of the development of today's urban environment. The identification and assessment of social, economic, ecological, cultural and spatial processes are prerequisites for an integrated approach to urban regeneration. Current urban development and urban administration combines complex challenges, which often can't be solved on a local scale even if the solution should be locally based. Thus, cooperation between different countries provides unique opportunity to collaborate, learn from each other, bring together knowledge and move in direction of sustainable urban development.

Despite the fact that time causes changes in the urban structure and the built environment of historic cities, their current vitality is highly dependent on the visual diversity and multifunctionality of the use of public open space. The development of digital technologies contributes to new challenges in the maintenance and management of public open spaces and allows more comprehensive public involvement in this process.

As theoretical research shows that bottom-up based complex and predictive modelling tools could serve as potentially valuable decision support platform for all stakeholders involved in processes of urban regeneration. The "capital" approach is a good starting point for such modelling because it structures urban complexity in a relatively simple and clear manner and could be based on quantitative mathematical approach which enables usage of various prediction techniques, e.g., artificial intelligence. On the primary phase, the "capitals" approach allows to identify opportunities and shortcomings of a certain tool and may be used as a basis for improvement and development of more integrative urban regeneration approach.

The proposed unified mathematical graph approach could be seen as one of the quantitative modelling tools for all four capitals and for modelling of their interactions. It could be supported by contemporary and available digital information tools. The presented example of Riga and other mentioned platforms could be seen as good examples.

Analysis of the existing DT shows a wide variety of tools and possibilities and possibility to address the capitals in either direct or indirect way. The presented classification can serve as a DT availability matrix while planning urban regenerations processes.

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