Geo-Design

Advances in bridging geo-information technology, urban planning and landscape architecture

RESEARCH IN URBANISM SERIES (RiUS) Vol. 4

Steffen Nijhuis, Sisi Zlatanova,
Eduardo Dias, Frank van der Hoeven,
Stefan van der Spek (Eds.)

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RiUS is a peer-reviewed and indexed academic publication series that deals with dynamics, planning and design in contemporary urban areas. It provides an outlet for investigation, analysis, and exploration in the overlapping fields of urban design, urban planning, regional planning, metropolitan design, spatial planning, urban renewal, urban management, landscape architecture, environmental design, sustainability, urban technology, urban mobility and cultural heritage.
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Editorial

Geodesign is a GIS-based planning and design method, which tightly couples the creation of design proposals with impact simulations informed by geographic contexts. Geodesign as such comprises a set of geo-information technology driven methods and techniques for planning built and natural environments in an integrated process, and includes project conceptualization, analysis, design specification, stakeholder participation and collaboration. Though the origins of this concept can be traced back to the early1960's – and without computers to the end of the nineteenth century – from 2005 onwards the term geodesign was introduced in order to (re-)present GIS (geographic information systems) as an instrument for planning and design. In fact it is an attempt to bridge the possibilities of geo-information technology and the needs of urban landscape research, planning and design. This is needed because often GIS is recognized as a useful tool but the potential of GIS is still underutilized in these fields, often due to a lack of awareness and prejudice.

Geo-Design. Advances in bridging geo-information technology, urban planning and landscape architecture brings together a wide variety of contributions from authors with backgrounds in urban planning, landscape architecture, education and geo-information technology presenting the latest insights and applications of geodesign. Geo-Design is here understood as a hybridisation of the concepts "Geo" – representing the modelling, analytical and visualization capacities of GIS, and "Design" – representing spatial planning and design, turning existing situations into preferred ones. Through focusing on interdisciplinary design-related concepts and applications of GIS international experts share their recent findings and provide clues for the further development of geodesign. This is important since there is still much to do. Not only in the development of geo-information technology, but especially in bridging the gap with the design-disciplines. The uptake on using GIS is still remarkably slow among landscape architects, urban designers and planners, and when utilised it is often restricted to the basic tasks of mapmaking and data access. Knowledge development and dissemination of applications of geodesign through research, publications and education therefore remain key factors. This publication draws upon the insights shared at the Geodesign Summit Europe held at Delft University of Technology in 2014. All contributions in the book are double blind reviewed by experts in the field.

The publication starts with a personal historical perspective by Carl Steinitz, one of the founding fathers of geodesign. Further contributions are organized thematically in three parts. The papers in part 1 focus on advances, applications and challenges of geodesign in spatial planning and design. Part 2 treats more specific issues and applications of geodesign related to land use, urban and facility management. Part 3 presents some interesting cases of geodesign education. While all the papers address the wider scope of geodesign they also treat synthetic positions that overarch the whole variety of aspects touched upon, either thematically or in a specific place.

An effort like this publication is only possible with the help and cooperation of many people. We would like to acknowledge: Henk Scholten, Shannon McElvany, Frank Holsmuller, Danbi Lee, amongst others, for their critical reviews and constructive comments on the papers. And finally we acknowledge TU Delft’s Faculty of Architecture and the Built Environment for its financial support.

– The Editors –

Beginnings of Geodesign
a personal historical perspective

CARL STEINITZ

Steinitz, C. (2016). Beginnings of Geodesign: a personal historical perspective. *Research In Urbanism Series*, 4(1), 9-22. doi:10.7480/rius.4.1366

Abstract

Geodesign is conceived as an iterative design method that uses stakeholder input, geospatial modeling, impact simulations, and real-time feedback to facilitate holistic designs and smart decisions. This paper aims to lay bare the beginnings of geodesign as such from 1965 onwards. It offers a personal historical perspective of Carl Steinitz, one of the protagonists in the field of geodesign. The paper describes some important milestones and influential people in a joint effort to bridge geo-information technology, spatial design and planning. It showcases the ongoing effort to employ the potential power of using GIS to link different model types and ways of designing to make better plans.

KEYWORDS

History geodesign; SYMAP; Computer models; Impact simulations; Landscape architecture; Urban planning

"Geodesign is a method which tightly couples the creation of proposals for change with impact simulations informed by geographic contexts and systems thinking, and normally supported by digital technology."

Michael Flaxman and Stephen Ervin, 2010

"Geodesign is an invented word, and a very useful term to describe a collaborative activity that is not the exclusive territory of any design profession, geographic science or information technology. Each participant must know and be able to contribute something that the others cannot or do not ... yet during the process, no one need lose his or her professional, scientific or personal identity."

Adapted from C. Steinitz, 2012, A Framework for Geodesign, Preface

My first contact with computing occurred in early 1965 at a lunch at the Harvard-Massachusetts Institute of Technology (MIT) Joint Center for Urban Studies, where I was a graduate student fellow. By chance, I was seated next to Howard Fisher, who was visiting Harvard while considering a move from the Northwestern Technology Institute (now Northwestern University) to the Harvard Graduate School of Design. Fisher, an architect, had invented the Synagraphic Mapping System - SYMAP - in 1963. SYMAP was the first automated computer mapping system that included spatial-analytic capabilities applied to spatially distributed data. It was based on line-printer technology. Its principal technical innovations for graphics were to enable the typeface ball on the printer to be stopped and a series of overprinting commands to be invoked, which then created a gray scale (Figure 1). SYMAP had not yet been applied to a substantive problem.

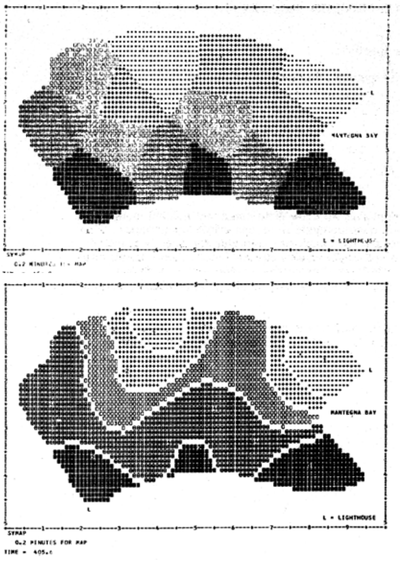


Figure 1. SYMAP Conformant map (top) and Contour map.

I immediately seized upon the relationship between the capabilities that Fisher described to me and the needs of my doctoral thesis on the perceptual geography of central Boston. With Fisher as my tutor, I gave SYMAP its first applied test. I was trying to explain why some parts of central Boston were included in Kevin Lynch's book Image of the City and some were not. I acquired data and mapped and analysed it, including via a graphic spreadsheet-type program, which I had to invent.

Partly because of this work, I obtained my first appointment at the Harvard University Graduate School of Design in 1965 as an assistant research professor and as an initial appointee to the then-new Laboratory for Computer Graphics. The Laboratory for Computer Graphics was established in 1965 with a grant of $294,000 from the Ford Foundation's Department of Public Affairs and various smaller contributions from and to the Graduate School of Design. Under Fisher's direction, the laboratory assembled a group of bright, energetic, and experiment-minded people, including urban planner Allan Schmidt, water engineer and economist Peter Rogers, and architect Allen Bernholtz.

The laboratory's research was basically of two types. The first was investigation into the analysis and computer-graphic representation of spatially and temporally distributed data and was built largely upon Fisher's SYMAP, which became in its time the world's most widely used computer mapping program. In a very short time, we developed several innovative methods of high-speed electronic digital computer mapping and new techniques for data analysis and graphic display. These made full and efficient use of the accuracy, speed, and cost of the computers of the time.

The second type was research in spatial analysis, mainly related to city and regional planning, landscape architecture, and architecture, with emphasis on the roles of computers in programming, design, evaluation, and simulation. For example, Frank Rens and his team were developing SYMVU, which was programmed to control the view angle and distance of plotted 3D data by enabling rotation of 3D volumes. This was a key step both for animation and for geographically focused global representations.

My assigned role in the lab was to represent landscape architecture and urban and regional planning. However, my personal experience at MIT in thinking about regional change as a designed process with Lynch and Lloyd Rodwin clearly led me to see (and perhaps foresee) computing as providing essential tools and methods for design (Figure 2).

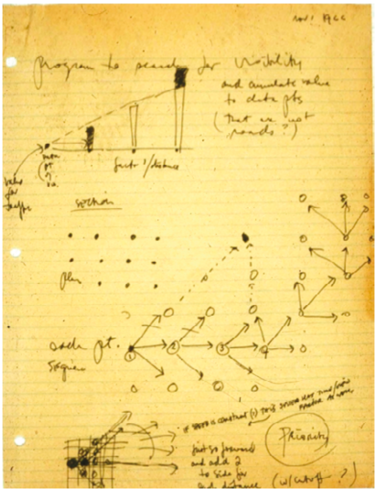


Figure 2. Ideas for analysing networks, such as streets, and for assessing moving views in 3D, 1966.

My first teaching assignment was in fall 1966 in a multidisciplinary collaborative studio, sponsored by the Conservation Foundation, that focused on future regional development and conservation of the Delmarva Peninsula (Delaware and parts of Maryland and Virginia). In this study, I and a small group of students chose not to use the then-common hand-drawn overlay methods being used by the rest of the class but rather to prepare computer programs in FORTRAN and use SYMAP to make and visualize a series of evaluation models for the future land uses under consideration. A design was made that was visually informed by the resultant maps (Figure 3).

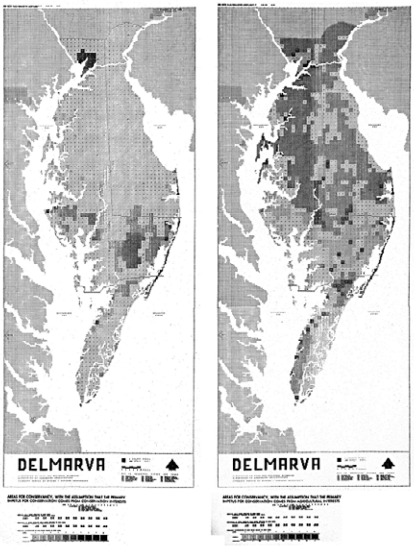


Figure 3. Data were combined using quantitatively weighted indexes to evaluate relative attractiveness for vegetable (left) and grain agriculture.

To my knowledge, the Delmarva study was the first application of GIS-modelled evaluation to making a design for a large geographic region. It is worth noting that this earliest GIS work was accomplished using Hollerith cards and the line printer to make paper maps in black and white. My first regional-scale GIS map was based on hand-encoded data to a grid base measuring two miles by two miles. It cost $35 (in 1965 dollars) for computing time on a $2 million IBM machine, the only accessible computer at Harvard. A registered user was only allowed one computer use a day. How happy I was to produce my first basemap, finally, after 30 days of effort.

Yet even in this first study, some rather sophisticated analytic steps were undertaken. These included a gravity model, various terrain-related analyses, the effect of one map pattern on another, and overlain data maps combined via quantitatively weighted indexes, such as the relative attractiveness for vegetable or grain agriculture. I cannot overstate the importance of the initial academic decision of Charles Harris, then chairman of the Department of Landscape Architecture, to support me to introduce GIS-based computing in a design-oriented studio rather than in a specialized 'technical/computer' course. This would prove crucial to the future development of GIS at Harvard as a set of methods for design.

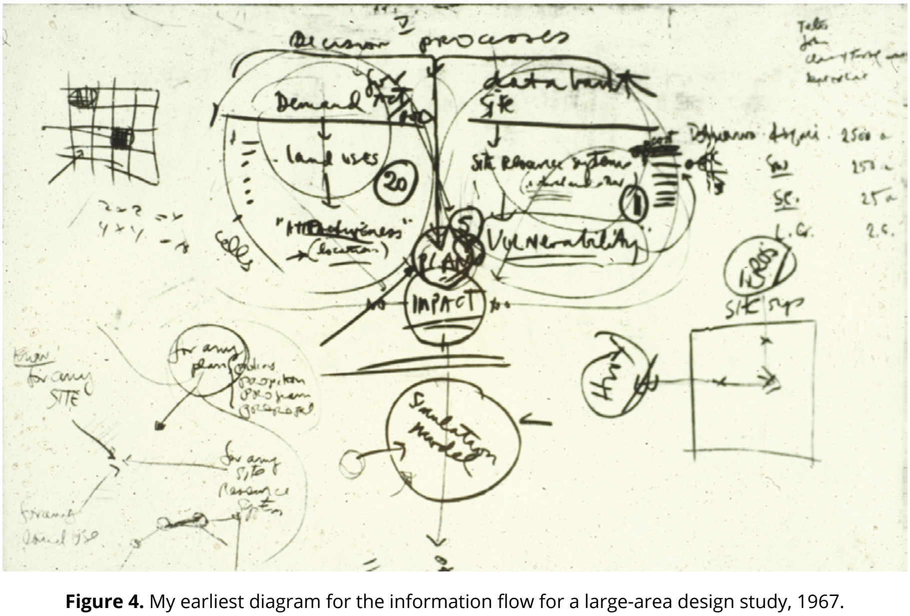


Figure 4. My earliest diagram for the information flow for a large-area design study, 1967.

In 1967, Rogers and I organized and taught an experimental multidisciplinary studio on the future of the southwestern sector of the Boston metropolitan region. The intent was to model the often-seen conflicts between the environmental vulnerability of the regional landscape and its attractiveness for development. We were also making a regional design for better managing the region's sprawling urban expansion. My initial diagram for this study was made in early 1967 and is shown in Figure 4. Note that it begins with an understanding of decision processes. It distinguishes between land-use demands and evaluations of their locational attractiveness and site resources and evaluations of their vulnerabilities. It assesses risk and impacts and proposes generating plans with the rules of a simulation model. It is organized in the same sequence now outlined in the second iteration of the framework in my 2012 book A Framework for Geodesign (although we didn't call our work that at that time).

Figure 5. Peter Rogers (left) and Carl Steinitz at the Laboratory for Computer Graphics, Graduate School of Design, Harvard University, 1967. Photographs of the process of working were taken only rarely, unfortunately.

The entire flow of information for the study was designed by Rogers and me before any 'work' was begun (Figure 5). The study area was a rapidly changing suburban area. There were no digital data, so the students organized a GIS from air photo interpretation based on a one-kilometer grid. (Remember, this was 1967.) Our students were also involved in all phases of the detailed specification, implementation, and uses of the models.

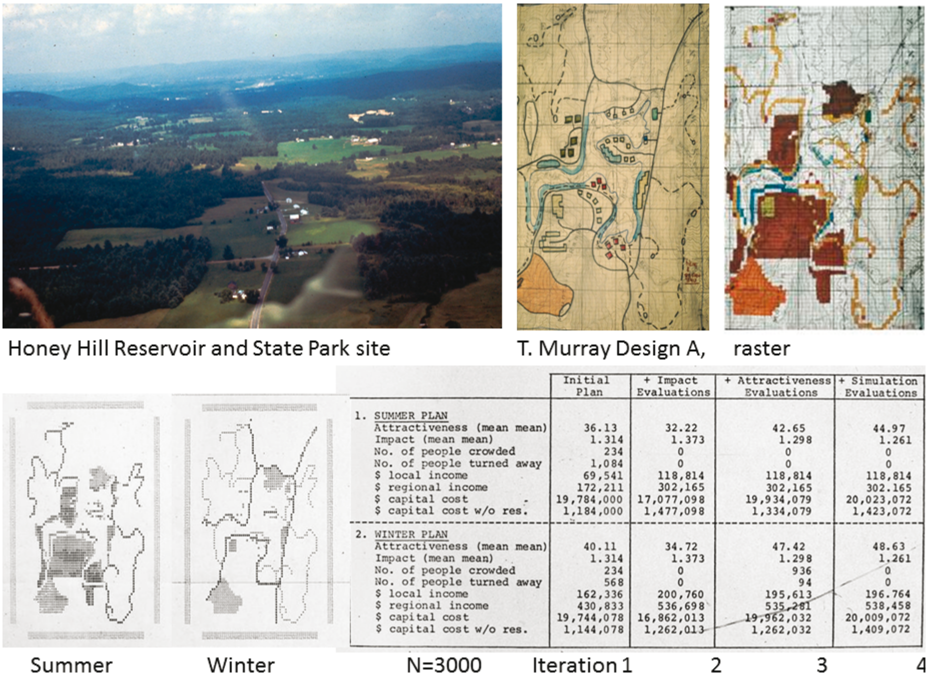
Ten process-related models were organized and linked, sharing what was then state-of-the-art GIS and programming software. Change was based on a demographic model that forecast population growth in different social classes and was allocated in five-year increments for a period of 25 years. These created demand for new locations to accommodate industry, three residential types, recreation and open space, and commercial/institutional centres. This new land-use pattern then required new transport services. Four purposely different types of impacts were selected for assessment: local politics, local finances, visual quality, and water pollution. If these were deemed unacceptable by the students representing the decision makers, several feedback paths would result in redesign toward an improved land-use pattern for that stage. If the impacts were satisfactory, the set of models would then be used to simulate the next five-year stage.

The evaluation of attractiveness or vulnerability for each land use in the future was based on a regression model of the locational criteria for that land use in the present. Computer-made maps, such as the following evaluations of locational attractiveness for low-, medium-, and high-income housing, were made by SYMAP.

While we were certainly aware of computer-based allocation models at that time, we deliberately had our students conduct the change model (the phase that changed the geography of the region) by hand, so that they would be as personally engaged as possible in the process. They made the allocations based on a smaller 250-meter grid, guided by the computer-generated evaluation maps.

These unit-areas of change were represented by color-coded cards for the land use to be allocated. The population model established the demand for each land-use type in a time stage, and then student teams, each representing different land uses, engaged in the physical and verbal process of competing for the most attractive locations, much in the way that an agent-based change model would function. They first simulated a future trend through the several time stages.

The students then assessed the consequences of the trend changes with the several impact models. These impacts were visualized by overlaying coloured pins and notes on the causal changes. The students then interpreted the impacts and decided whether changes in the trend's land-use pattern of any stage were required. Lastly, they re-allocated the changes by design, producing results measured to be environmentally superior and meeting the criteria for development (Figure 6). This Boston study was published in 1970 as A Systems Analysis Model of Urbanization and Change: An Experiment in Interdisciplinary Education (MIT Press).



	Initial Plan	+ Impact Evaluations	+ Attractiveness Evaluations	+ Simulation Evaluations
1. SUMMER PLAN				
Attractiveness (mean mean)	36.13	32.22	42.65	44.97
Impact (mean mean)	1.314	1.373	1.298	1.261
No. of people crowded	234	0	0	0
No. of people turned away	1,084	0	0	0
$ local income	69,541	118,814	118,814	118,814
$ regional income	172,211	302,165	302,165	302.165
$ capital cost	19,784,000	17,077,098	19,934,079	20,023,072
$ capital cost w/o res.	1,184,000	1,477,098	1,334,079	1,423,072
2. WINTER PLAN				
Attractiveness (mean mean)	40.11	34.72	47.42	48.63
Impact (mean mean)	1.314	1.373	1.298	1.261
No. of people crowded	234	0	936	0
No. of people turned away	568	0	94	0
$ local income	162,336	200,760	195,613	196.764
$ regional income	430,833	536,698	535,281	538,458
$ capital cost	19,744,078	16,862,013	19,962,032	20,009,072
$ capital cost w/o res.	1,144,078	1,262,013	1,262,032	1,409,072

Figure 6. Upper: The structure of the study's ten linked models, attractiveness for new middle-income housing, and allocating new development and conservation. Lower left: Trend growth (top three images) and improved growth (bottom three images). Lower right: Dust jacket of A Systems Analysis Model of Urbanization and Change, 1971.

Also in 1967, our research group, which included landscape architects Richard Toth, Tim Murray, and Douglas Way and engineer-economist Rogers, began a series of GIS-based studies that related various ways of making and comparing designs for large and environmentally vulnerable geographic areas with complicated programmatic needs. The Honey Hill study, named after its location in New Hampshire, was sponsored by the US Army Corps of Engineers. It involved a large proposed flood control reservoir and a new state park. GIS-based evaluation models were made of the attractiveness of this large area for recreation and other uses and of the vulnerability of the site's natural systems to harmful impacts. Each member of the research team then proposed a design for the new lake and park facilities, in summer and winter (Figure 7). In addition, Rogers used a linear programming algorithm to produce a fiscally optimal plan.

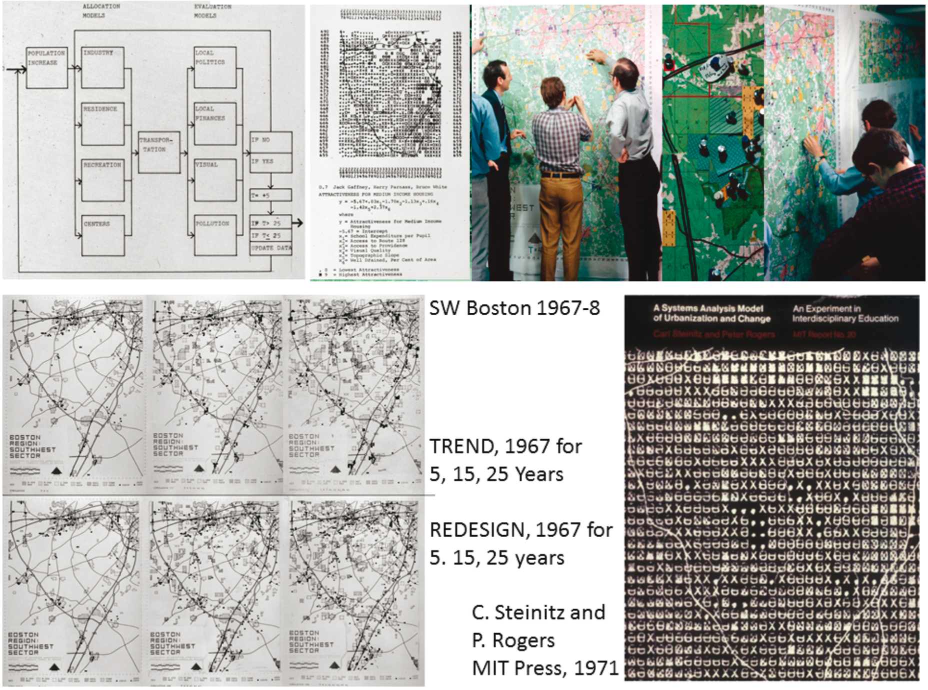


Figure 7. Top left: Aerial view of the site. Top right: Tim Murray's design. Bottom: Assessment of impacts of Murray's design.

These alternatives were all compared in yet another model, which simulated several levels of population demand and user movement to the area's facilities based on varied assumptions regarding number of persons and patterns of activity preference. Overcrowding and movement to second-choice locations or activities and capital and maintenance costs for the design alternatives were among the comparative impacts. Each design went through three iterations of assessment and redesign. The optimizing program performed best, and my design came in fourth.

This study provided important insights into the potential power of using GIS to link different model types and ways of designing to make better plans. This experience would shape our work for many years and, in my own case, to the present time. This research concept was the inspiration for a series of studies focusing on the Boston region in the late 1960s, as well as a major research program supported by the United States National Science Foundation in the early 1970s, which integrated GIS methods with sectoral models of the processes of urbanization and change. Two additional early experiments may be of interest. In 1968, I designed a series of programs that automated the process of placing a series of pre-packaged visual simulation forms for trees, houses, etc., on a raster terrain model and a land-cover map (Figure 8). This program set then allowed one to specify the location and azimuth for a view or sequence (based on the work of Rens), and a pen plotter would painstakingly draw a series of perspectives in that GIS-generated landscape. The system was configured so that changes in the GIS terrain or land-cover map would automatically trigger changes in the landscape view. This technique was successful as an experiment but inefficient and uneconomical. It took several years before we efficiently linked GIS to automated allocation and animated visualization.

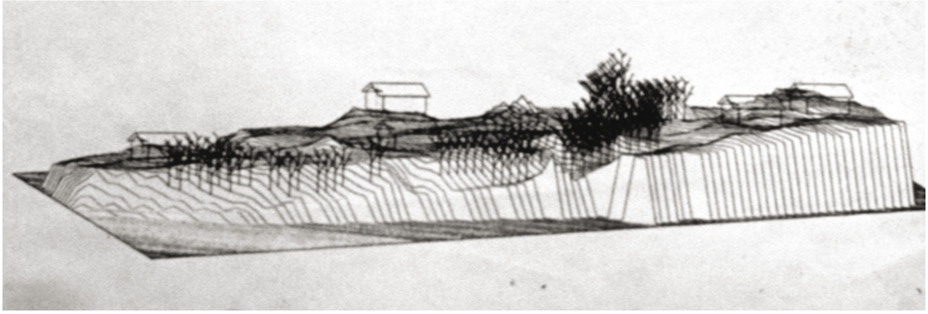


Figure 8. Buildings and trees on terrain.

Also in 1968, and having made several experiments placing and visualizing a designed pattern of land uses on terrain, I had a series of discussions with architect Eric Teicholz about different ways in which rules could be established for the making of the designs themselves. We decided to make a series of experimental designs, which were rule based. There would be a street system and a pond, each with minimum setbacks; parking access within a minimum distance to every house; three housing types with pre-specified locations for connections; and trees, which were allocated along roadways or near houses but could only be located on soil. The experiments varied the number of houses among the three types and the number and roles of trees.

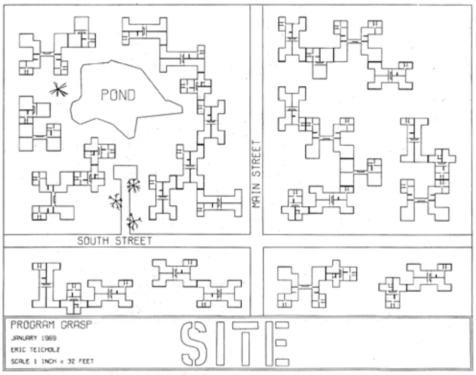


Figure 9. Our first experimental computer-generated, rule-based design (E. Teicholz with C. Steinitz).

Figure 9 shows the first experimental rule-based design. In retrospect, I would divide these earliest years of GIS and its applications into three stages. In the middle 1960s, we used computers and computer graphics to do things we already knew how to do using non-computer technologies. We acquired data and encoded it and produced maps. The analytic capabilities of the time were primitive, typically limited to applied studies on landscape classifications, sieve maps, or overlay combinations, all of which could have been accomplished with hand-drawn methods. Spatial and statistical analyses were difficult; professional acceptance was low, and public cynicism was high regarding analyses and the resultant graphics produced by computers.

The second stage, in the later 1960s, emphasized substantially more sophisticated GIS analyses: the merging of mapping and statistical techniques, the introduction of more sophisticated spatial analysis methods, and the introduction of graphic displays more diverse than two-dimensional maps. A strong research effort in theoretical geography was organized and directed by William Warntz and related to the theory of surfaces, the macro-geography of social and economic phenomena and central place theory.

During the third stage in the early 1970s, the laboratory saw important interaction with other disciplines and professions, particularly the scientific and engineering professions. We had the self-criticism that recognized the need for more predictable analysis and for better models. The view throughout this third stage was that information could and should influence design decisions. A critical professional role would be to organize that information, have it available and adaptable to questions, and thus provide decision makers with information relevant to decisions at hand. The focus on aiding decisions rather than making decisions increased both public and professional interest and acceptance.

I ended my direct affiliation with the laboratory in this period. By then, we had developed, demonstrated, and occasionally linked and used computer software to fully support a variety of design processes. We had collaboratively applied these to significant studies of real, large, and complex places . . . the stuff of geodesign.

The laboratory continued to grow in size and influence under the further directorships of Warntz and Schmidt. The later 1970s to the mid-1980s may be characterized by the introduction of smaller and far less expensive computers, more user-friendly programs incorporating commands in common English or the ability to point a computer cursor, more easily acquired data, and a proliferation of analytic and graphics capabilities. These advances resulted in an increased potential for decentralized and networked computer use and in increased freedom from predefined analysis and planning approaches. However, the need – and responsibility – for selecting wisely from a much larger set of technical and methodological options also increased in this period. We saw in the universities and then in the professions the first computer-comfortable generation of students. Professional acceptance broadened, and computer use was no longer regarded as something special.

The Harvard Laboratory for Computer Graphics and Spatial Analysis ceased to exist – for many complex reasons – in 1981. By then, 165 people had served on the laboratory staff at one time or another. Much of the credit for the lab's diverse accomplishments should go to Fisher, who died in 1974 and who was a remarkable person of uncommon energy and foresight. The many individuals linked to the lab and their ideas, computer programs, demonstrations, publications, and especially students were significant contributors to the development of today's GIS and many of its applications, including geodesign.

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SPATIAL DESIGN AND PLANNING

Integrating Virtual Reality, Motion Simulation and A 4D GIS

JUERGEN ROSSMANN, ARNO BUECKEN, MARTIN HOPPEN, MARC PRIGGEMEYER

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Abstract

Geodesign requires the visualization of concepts and ideas within a context of geo-information of the respective place in a way that is understandable to people with different backgrounds – planners, geographers, architects, but also the users or inhabitants of the place. All of the roles involved have different requirements and need different information to fulfil their tasks within the geodesign process. In this contribution, we present the structure of a software system combining a GIS, a simulation system and a VR component, as well as interfaces to different interaction devices (like a GPS receiver, a spacemouse, multi-screen projection systems or devices for haptic feedback). This enables simulations of the place in its geographical context, as well as immersive presentations that are understandable regardless of the knowledge of a plan's symbolic language. All this happens without the need to convert frequently between the software tools that are commonly used by the different roles.

KEYWORDS

Virtual reality; Motion simulation; 4D GIS; Geodesign; Virtual Forrest

1. INTRODUCTION

According to Steinitz (2012) Geodesign "is the development and application of design-related processes intended to change geographical study areas in which they are applied and realized". He states that collaboration between the different roles involved in a geodesign process can be challenging. Therefore an intuitive visualisation of the steps and results is an essential part of a successful geodesign process. This goes together with the evolution of geographic information systems (GIS) from 2D to 3D, which happened in recent years, By now, some approaches even consider time as a fourth dimension. Visualization of the corresponding data moved ahead from simple maps towards three-dimensional landscapes and cities. However, in most cases, it is limited to a single display on a single computer.

In this contribution, we present an approach of a fully integrated 4D geographic information and virtual reality (VR) system. While data management is based on OGC (Open Geospatial Consortium) standards like the Geography Markup Language (GML), it supports the synchronization of multiple clients and allows rendering views for multiple screens – even for a seven screen panoramic projection system or a CAVE environment. Besides VR-style visualization techniques, it is also possible to use the data for simulation or to even feel it with a motion simulator system.

We will describe the synchronization of multiple computers, the visualization component and the use of a highly versatile motion simulator, which is based on an industrial robot. Several aspects like the used washout filter and the physiological foundations that enable the use of a robot with a still limited workspace to display poses and forces in a large world are introduced.

The rest of this paper is structured as follows: The next section illustrates, how we extend a 3D simulation system by GIS functionality. In the next section, we describe the simulation system's VR capabilities. Subsequently, the motion simulation approach is presented. The contribution ends with a conclusion of the presented work.

2. CREATING A GIS FROM A 3D SIMULATION SYSTEM

Most software environments require multiple independent components for editing and displaying 3D geo-data. While standard GIS provide a 2D top view on the scenery and in some cases a 2.5D or even a rather limited 3D view, additional software is needed to display the same scenery on large scale displays or in virtual reality systems. The disadvantage of multiple software products in the tool chain from data editing to the impressive visualization is the frequent need to convert and exchange data.

The presented approach was developed for a forest information and simulation system that required a number of algorithms and user interface approaches, which were already implemented in VEROSIM, an existing 3D simulation system. Originally, this system was developed for the simulation of robotic work cells, but has since been enhanced to a variety of applications from the fields of industrial automation, space robotics and environment. Thus, for the latter, instead of starting with a standard GIS, support for standard geo-data modelling and interfaces for geo-databases like SupportGIS Java (SGJ) or native PostgreSQL/PostGIS were added to the existing VEROSIM.

2.1 Flexible Database Interface

For accessing (geo-)databases from a simulation system, a flexible yet efficient concept was developed (Hoppen, Rossmann, Schluse, & Waspe, 2010). Its basic idea is to synchronize a simulation system's internal runtime database with the central database on schema, data and functional level. Using schema synchronization, the simulation system adopts the schema from the central database once during system start-up so both systems "speak the same language". Subsequently, data conforming to this schema can be replicated to the simulation database, on-demand. For example, driving a virtual car through a large forest model, spatially nearby data (e.g. surrounding trees, tile data) is loaded into the simulation database while objects are unloaded when they are left behind. Thus, the simulation database can be seen as an "intelligent", real-time capable cache for the central database. The approach also allows modifying replicated data. Here, change notifications are used to synchronize updates between the databases (Hoppen, Waspe, Rast, & Rossmann, 2014). Thus, when synchronizing multiple simulation clients to the same central database, it cannot only be used for data management, but also as a communication hub for the shared simulation model.

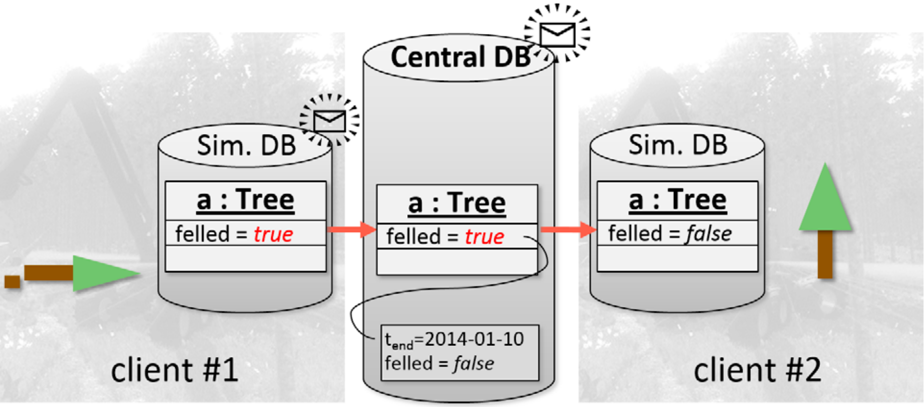

Figure 1. The architecture of the database synchronization approach.

In Figure 1, an exemplary synchronization scenario is shown. Two simulation clients with their respective databases (#1 and #2) are connected to a central database containing a simple 'Tree' object with a 'felled' state. The object is replicated to both clients. Client #1 changes the state to 'true' and syncs it to the central database where the previous value is versioned with a timestamp tend. Subsequently, a notification sent to client #2 allows it to adopt the change. Finally, besides schema and data synchronization, functional synchronization is used to translate semantics between the systems. For example, the transformation matrix of a CityGML (Kolbe, Gröger, & Plümer, 2005) implicit geometry is translated to a data structure known to the simulation system's render engine. Altogether, for the presented work, this database synchronization concept was realized using the VEROSIM Active Simulation Database (VSD) and SGJ.

2.2 Temporal Data Management

Additionally, basic GIS functionality required for editing the stored data was implemented, e.g., for measurement, vector or raster editing, or gradient visualization, yielding a 3D simulation system with an integrated GIS. In order to capture and reproduce the changes of the 3D forest model (or any other model), we added time as a fourth dimension (Hoppen, Schluse, Rossmann, & Weitzig, 2012). This is realized by using a temporal database (Jensen, & Dyreson, 1998) as the central geodatabase. When changing data in a temporal database, its previous state does not get lost, but is preserved in terms of historic versions that are still accessible by the user. As geo-data represents the state of real world phenomena at one or more points in time, a temporal database allows capturing this inherent time dependence. Different interpretations of time, so-called time dimensions, may be applied. A transaction time database automatically associates committed timestamps with any change. In contrast, in a valid time database, the user (or some process) assigns timestamps that represent the point in real time a change has taken place or will take place. Both concepts can even be combined, yielding a bi-temporal database. Using the aforementioned database synchronization concept, a temporal snapshot is replicated to the simulation system's runtime database. For that purpose, the user specifies a reference time within the simulation system. On changing this reference time, the snapshot gets updated accordingly. When altering the replicated data within the simulation system's database, synchronized changes are versioned within the central, temporal database. Figure 1 shows an example, where a change from a simulation client is replicated to the central temporal database. Here, the previous value ("false") becomes a historic version before the new value is adopted and a notification is emitted.

2.3 Client Synchronization

Note that all these mechanisms are independent of the actual data model and can be transferred to other (geo-)data than trees and forests. Thus, the very same approach can also be used to monitor the change in urban areas, e.g. using the CityGML data model, but also other common formats like IFC (Industry Foundation Classes), STL (STereoLithography) and many others are supported.

Figure 2. Example scenario for database synchronization.

Furthermore, our approach allows the synchronization of multiple independent clients either by a simple property synchronization mechanism, a fully-fledged distributed simulation protocol, or by using a central, active geo-database (Hoppen et al., 2014) as presented above. This allows to either link multiple displays for CAVE environments or multi-projector panoramic projections, or to generate independent views of the same scenery for several users. The approaches can even be combined so that each connected client can in turn use multiple screens. Figure 2 shows an example using combined synchronization approaches: the simulation model is managed by a central geo-database and replicated to two clients (jeep on TV, helicopter on multi-projector panoramic projection). The projection system itself distributes the simulation to six slave systems for rendering the three stereo images.

3. VIRTUAL REALITY

There are multiple virtual reality applications that deal with geo-information. Examples are landscape visualization, architecture as well as simulation of cars, aircrafts or other vehicles. In most cases, it is required to export the geo-data and convert it to some 3D format like DXF (AutoCAD Drawing Exchange Format) or IGES (Initial Graphics Exchange Specification) in order to use it in a simulation system. In the presented system, however, the integrated 3D renderer of VEROSIM is activated, the view is changed from 2D orthogonal to a 3D perspective projection and – if required – multiple computers are linked together with the synchronization approach described above. On each computer, the view frustum can individually be adjusted, allowing to define stereo views (where two computers render the images for the right and left eye), panoramic views (using adjacent screens) as well as a combination of both. The renderer supports different lighting situations, change of daytime, different weather scenarios and even the photorealistic visualization of natural objects. Figure 3 gives an example with a virtual city guide. The performance of the renderer scales with the hardware of the computer. On a standard PC with a graphic board designed for computer games it is possible to visualize environments with eighty million vertices at forty frames per second. 2D geography features can simply be projected on a 3D ground. It is also possible to use metaphors for this information – like an auto-generated fence for a surface feature representing property boundaries.

Figure 3. A virtual city guide.

The software system also offers physical simulation of objects. This way, it is possible to use the geo-data for simulation purposes. The objects can be controlled by the user with several different interaction devices like a wireless six DOF (degrees of freedom) tracking system, data gloves, a spacemouse, joysticks or even a dedicated hardware like a harvester seat with the manufacturer's on-board computer. The simulation can be configured in a way that the results or performance logs are also geo-coded. Therefore, it is possible to study and discuss results of the simulation in the corresponding environment. Examples of geo-coded logs are track-marks or geo-coded notices which can be displayed as a small sign.

4. MOTION PLATFORM

Although providing a deep visual immersion, it is still difficult, e.g., to estimate the real inclination of a hill or the effort needed to follow a steep road. This impression, however, can easily be achieved by moving the user according to the hill's slope. There are several approaches for this so-called motion cueing. Conventional approaches mostly utilize a Stewart/Gough platform, a hydraulic hexapod that allows moving the top plate in six dimensions. This system is scalable from a small installation, which can only carry a seat with a single person and a data helmet, towards a solution that moves a flight deck or a ship's bridge for professional multi-user training applications.

Due to their mechanics, all Stewart/Gough hexapods are limited in their rotatory movement. Thus, steep inclinations cannot be simulated with these devices. A more advanced approach is a motion simulator based on an industrial robot. While the main disadvantages against the hexapod are a lower maximum payload and a larger space requirement, the motion simulator benefits from the versatile movements of the industrial robot. With this device, even an overhead situation becomes possible.

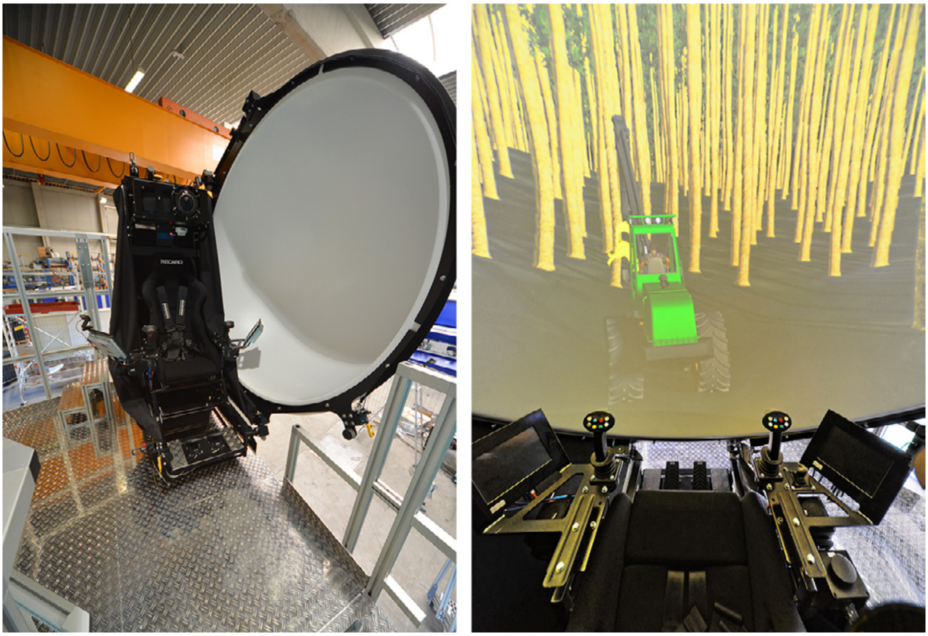

Figure 4. The capsule of the motion simulator.

For the work described in this contribution, we decided to use a robot-based motion simulator with a small capsule, which is equipped with a 180 cm wide hemispherical screen in front of a high resolution 3D projector with a fisheye lens above the user as well as a stereo sound system (Figure 4). For user interaction, the capsule provides two touchscreens, which can be used to display instruments or additional information, two three-axis joysticks, two pedals and a throttle control. The capsule is equipped with an opaque textile cover that keeps out visual impressions from the outside providing a better immersion.

Figure 5. The motion simulator system.

Our system features a KUKA KR-500 TÜV robot, a six-axis industrial robot with a maximum payload of 500 kg. This is sufficient for the capsule including all installed electronics and a passenger with up to 120 kg (Figure 5). The robot operates in a work cell with a diameter of approximately 10 m and requires a height clearance of about 7 m. The capsule can be accessed in a height of 2.4 m by using a staircase and a retractable platform. To ensure the user's safety, the capsule is equipped with a bidirectional audio link, a video downlink and a smoke detector. The robot is hardware-restricted in its movements to avoid collisions between the capsule and the ground as well as between the capsule and the robot. Furthermore, the robot control includes an acceleration limit to control the forces that are applied to the user. The impacts are limited according to DIN EN 13814 (DIN, 2004), but still the user feels accelerations up to 2 g.

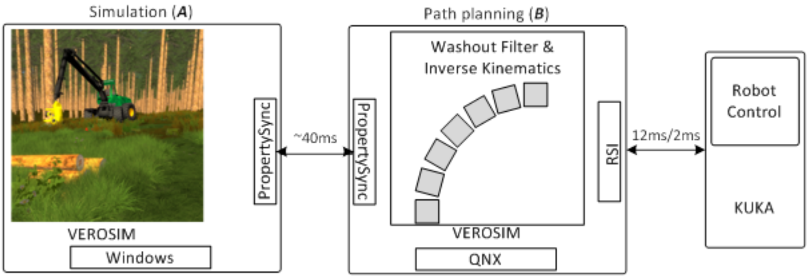

Figure 6. Components involved in motion cueing.

4.1 Motion Cues

The benefit of this six-degrees-of-freedom robot is the precise mapping of simulated movements and accelerations onto a pose in the real world. This way, an attached seat can be positioned and oriented according to the user's situation within the simulation. For example, in the simulation of a wood harvester (Figure 6, left), when a driver navigates through a forest, passing through rough terrain and evading obstacles, it is invaluable for a realistic simulation to extend the 3D visual information with a tactile element. In contrast to smaller screens, the hemispherical projection provides for the possibility of strong peripheral visual cues. These motion cues are caused subconsciously by motion visually observed in the peripheral field of view. Different researchers have already put huge efforts into studying these effects. Their conclusion is that these cues already provide a very strong motion feedback, but they can still be amplified by motion observed through the vestibular system (Telban, 2005).

The vestibular system responds differently to translational and rotational motion. Due to the robot's construction, there is a strong influence on the semi-circular canals and, therefore, motion perception due to extended rotations is intensified by design. Nevertheless, since thresholds for the human motion perception have been proposed (Zacharias, 1978), strong jerking movements can be utilized to convey translational accelerations by stimulating the otolithic organs.

By computing the appropriate robot motion in real-time, the driver's motion and the visual feedback can be synchronized for a holistic driving impression (Telban, 2005). This can be achieved by estimating motion cues caused by a vehicle and induced to a passenger. By calculating accelerations of the passenger frame with a subsequent washout filtering, a motion subset can be estimated that can be used to stimulate a passenger's vestibular system causing the relevant motion cues. Additionally, the passenger perceives the visual motion cues due to her peripheral field of view.

The washout-filtering step is essential to provide measures for the limited workspace of the robot (Grant, & Reid, 1997). Since a vehicle in the real world can move freely, with regards to its physical behaviour, while the passenger seat's motion envelope in the simulator is rather limited due to the constraints of the robot, a mapping of the motion has to be applied. Models of the human inner ear can be applied to preserve the perceived motion. Since the semi-circular canals as well as the otolithic organs can be modelled as damped systems (Zacharias, 1978), only parts of the actual motion are perceived until the "washout" masks others. Thus, it is possible, e.g., to stop accelerating the capsule in one direction after a short period of time and then to slowly move backwards to the pristine position for further motion induction without the passenger noticing.

This motion has to be performed by an actuator, e.g., a six-axis robot like our motion simulator, carrying a capsule providing a passenger seat. For this robot to move, an interface to the manufacturer's robot control system has to be provided. In general, such an interface needs to meet hard real-time constraints specified by the manufacturer, which are specific to a particular robot control system. Communication protocols, simulation, planning and execution are separated onto different machines constituting a distributed simulation. This way, time critical parts of the software are detached from the non-time-critical parts and executed on dedicated computers providing enough computing resources to meet the specified constraints.

4.2 Distributed Simulation

The simulation comprises different computers to carry out specific tasks (Figure 6). Computer (A) either runs a Windows or a Linux operating system. It provides a platform for VEROSIM to simulate a vehicle's dynamics and the environment it interacts with. For a realistic simulation, the vehicle's model is composed of different parts with different masses. A wheel suspension modelled as a damped mass-spring system is attached to provide realistic interaction between rough terrain and the vehicle (Jung, Rast, Kaigom, & Rossmann, 2011). In the example of the wood harvester, the vehicle also has a crane to grab and work on tree trunks. As this provides a huge level of interaction between vehicle and environment, it also provides a huge potential for a realistic motion feedback.

The motion feedback is calculated on computer (B) by transforming velocities and accelerations into new poses and robot trajectories. It runs the QNX operating system with its pre-emptive scheduler (Hildebrand, 1992). This is a mandatory component of the whole setup to meet the real-time constraints imposed by the Kuka Robot Control (KRC2). A sampling frequency of 1/12kHz has to be attained to achieve smooth robot motion. Thus, the QNX system clock runs with a 1 ms resolution to provide a fine granularity for the VEROSIM task scheduler.

To cope with the inverse kinematics and path planning, the simulation system VEROSIM uses a model of the physical robot and its environment. This model is used to evaluate the motion, considering the available workspace and robot constraints. These constraints are imposed by limits for the axis' positions, velocities and accelerations. By exceeding any of these limits, the robots movement is stopped and an error message is issued to signal a fault state. Because this also prevents the simulation from continuing, the robot constraints have to be strictly adhered to, to prevent a passenger from uncomfortable accelerations.

When a target pose is calculated that exceeds the robot limits, steps have to be taken to move the robot in a way to minimize the wrongly perceived motion cues. One examined approach was to move the robot to its farthest possible Cartesian position and then only continue moving those axes that are sufficiently far away from their limits to provide a smooth stop.

Two different approaches were implemented to compute velocity profiles for the robot to follow. When a velocity profile is calculated, it is used to interpolate new target positions for the robot's axes. These positions are set by the internal position controllers of the KRC2.

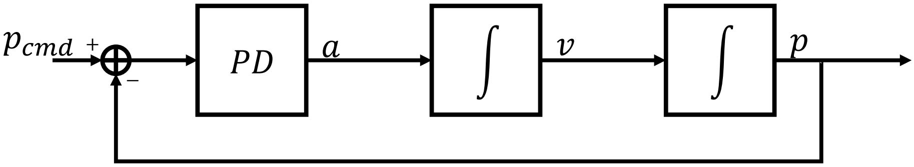

Figure 7. Linear control model for accelerated motion.

The first approach utilizes a simple linear model describing accelerated motion (Figure 7). Accelerations (a) are integrated twice (with the velocity (v) as intermediary) to provide positions (p). Since positions are controlled by accelerations, a closed-loop linear controller is necessary to ensure a stable system behaviour. The controller is implemented with the PD (proportional-derivative) control algorithm comparing the desired position (p_cmd) with the actual position (p). The controller is parametrized to provide small system response times while being stable with little overshoot. Subsequently, the acceleration values are truncated to fit the robot acceleration limits.

The second approach parameterizes cubic hermite splines to describe a velocity profile. When a new target position is received, it is taken as the spline's final point setting the velocity to zero. Accordingly, the robot's current position and velocity is used for the spline's starting point. This allows coping with two scenarios. First, no new target position is received until the spline's final point is reached. Thus, the robot is stopped and waits for new commands. Second, a new target position is received while the robot is still moving. Since the current position and velocity is used to calculate a new profile, the current one can be replaced by the newly computed velocity profile without causing jerking behaviour.

Either way, resulting poses of the simulated robot are sampled with a frequency of 250Hz and subsequently used as target values for the internal position controllers of the KRC that move the physical robot accordingly.

To provide target positions for the previously described approaches, a washout filter was implemented being the basis for the whole motion cuing process. To this point, a classical washout filter design (Krämer, 2004) has been utilized on computer (B), executed with a frequency of 250 Hz. A basic layout of this filter is depicted in Figure 8. Three main parts can be identified that operate in close coordination. For all of them, the vehicle simulation has to provide accelerations (a,) that are separated into a translational and a rotational component. The translational component is utilized by the tilt coordination (TILT, Figure 8) as well as the high pass filter (HP, Figure 8 top) for the translational motion. Since the translational high pass filter removes low frequency components, which would be useful for long acceleration phases in vehicles, the tilt coordination transforms these low frequency accelerations into an orientation that is applied to the passenger seat. This way, the earth's gravitational force is used to display accelerations that would otherwise be lost.

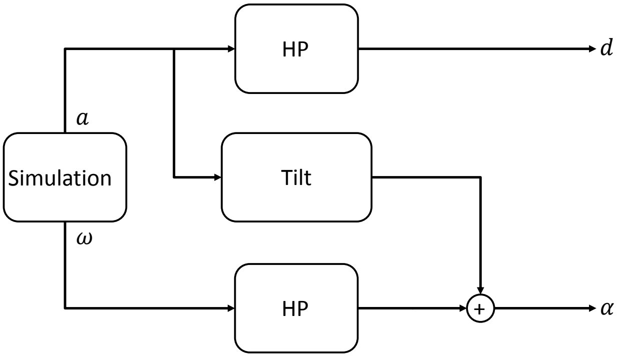

Figure 8. Basic washout filter principle.

These changes in orientation will ultimately induce rotational motion cues if performed too rapidly. Since thresholds for the perception of these changes exist, the effects can be compensated. As with translational accelerations, rotational accelerations are also high-pass-filtered (HP, Figure 8 bottom) to remove unacceptably long acceleration phases that would cause the robot to move outside its predefined limits. However, low frequency components are processed differently as there is no counterpart to the tilt coordination. Thus, they are lost and cannot be utilized in motion cueing.

The filtered accelerations (d,) can be used to control the robot motion. To guarantee the capsule to return to its pristine position, a linear controller is used. The controller is parameterized to keep accelerations for this motion below perceptual thresholds to avoid the induction of false motion cues. The pristine position has to be chosen carefully to provide for a maximum flexibility in the consecutive movements. The aforementioned lengthy acceleration phases might exhaust the robot's workspace reducing otherwise possible motion cues.

4.3 Synchronization

Different computer systems are combined to provide a distributed simulation for our motion simulator. All computers have a specific task to perform and, therefore, have to synchronize specific properties. As mentioned above, VEROSIM provides a simple property synchronization mechanism (Hoppen et al., 2014). It can be used to replicate individual properties of the simulation model between VEROSIM instances on different computers. Every time a property is modified, the new value and its timestamp are sent to all other connected instances.

The VEROSIM instance on computer (A) simulates a vehicle whose seat's frame is used as an input frame for the washout filter. As the washout filter is executed on the QNX VEROSIM instance on computer (B), the seat's frame has to be synchronized between both instances. Hence, computer (A) acts as a server for computer (B) and changes of the seat's frame are sent to computer (B) where the appropriate accelerations for the translational and rotational components are calculated for further processing.

As this synchronization is a non-time critical part of the simulation, frames are not sampled at fixed rates, but rather as soon as changes occur. Therefore, as the vehicle simulation on computer (A) is carried out with an update frequency of 25 Hz to 30 Hz, new samples arrive at the least every 40 ms.

4.4 Robot Control

For its KRC2 robots, KUKA provides a control panel that can be used for robot control. It is a graphical user interface to display variables, states and system information. It can also be used for writing KRL (Kuka Robot Language) programs to be executed on the robot's real-time hardware. Furthermore, it allows to directly moving the robot with a simple keystroke. Even though this enables the user to easily manipulate the robot's position, it is not sufficient to implement large sensor applications or applications dependent on external path planning.

For such applications, KUKA provides the Robot Sensor Interface (RSI) technology package. It is a KRL application-programming interface comprising function blocks that can be connected into block diagrams implementing complex algorithms. On the KRC2, the RSI programming is carried out using KRL code to instantiate blocks and manually connect them by function calls. When the RSI definition is finished, a function call can pass control over the robot position from the integrated control panel to an external system by entering the so-called sensor driven mode. This mode enables the RSI function blocks and, therefore, causes an override of the user interface.

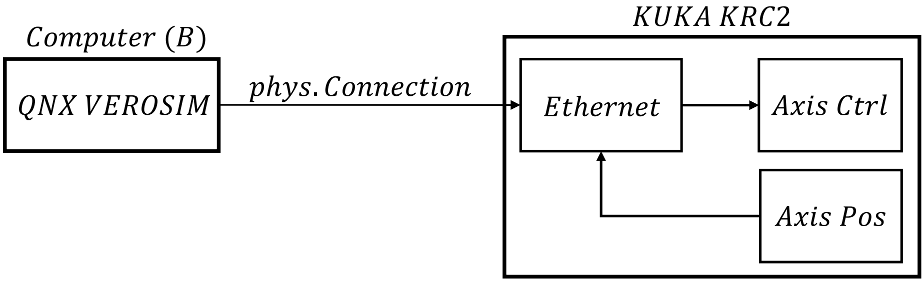

Figure 9. Position control integration with the Robot Sensor Interface.

For our motion simulator, a block diagram as depicted in Figure 9 (right) is implemented. A function block is instantiated for Ethernet connectivity (Ethernet), axis control (Axis Ctrl) and position sensor (Axis Pos). This way, new positions can be commanded via Ethernet to be applied to the robot's axes. The axis control block passes positions to the internal position controller and makes the robot move. The robot's current position is also transmitted back to the external system (QNX VEROSIM) via Ethernet (Figure 9 left). Thus, here, a closed-loop feedback controller for the motion feedback algorithms can be implemented on Computer (B) as well.

On the QNX computer, VEROSIM is executed as a real-time process and is connected to the KUKA KRC2. As mentioned above, its primary task is to execute a simulation of the robot kinematics and to calculate velocity profiles for the physical robot to follow. Thus, the QNX VEROSIM opens a data channel to the Ethernet function block running in the RSI block diagram and replicates the simulated robot's motion by commanding positions sampled from the velocity profile. Since the RSI Ethernet block demands a 12 ms time slot, new positions are sampled asynchronously with a 1/12 kHz frequency.

A combination of these techniques yields a simulation system that provides holistic driving impressions. A passenger driving a simulated jeep (Figure 10) can see and feel accelerations by steering a vehicle through simulated terrain in a realistic manner. For example, while driving a long left-hand curve the motion simulator capsule is moved likewise to induce the realistic driving impression. Figure 11 gives an impression of the motion simulator's dynamic behaviour.

Figure 10. Motion simulator responds to left-hand curve of simulated jeep.

Figure 11. An impression of the motion simulator's dynamic behaviour.

5. CONCLUSIONS

Altogether, the presented combination of a 3D simulation system with VR, GIS and motion simulation functionalities provides a fully integrated virtual reality and GIS approach. It reduces the usually required tool chain to a single software, eliminates the need to permanently import and export data between multiple systems and adds the possibility to interact with the geo-data like in a common GIS even when displayed in a VR system. It becomes possible to change object data in the GIS, even to generate live maps from the geo-data and to immediately explore the results in the virtual reality environment. On the other hand, georeferenced simulation results can be evaluated with all available GIS tools, which is one of the ideas of a Virtual Testbed (Rossmann, Jung, & Rast, 2010). For example, performance logs of a harvester can be combined with 2D or 3D maps and displayed in the GIS or VR view.

The haptic feedback from an industrial-robot-based motion simulator adds even more information about the geo-data to the impressions of the user. Movements of the camera or of any simulated object within the geo-data are converted to robot movements by using washout filters which consider the limits of the physiological movement perception of a human. These calculated movements are then passed to the robots inner control loop in a real-time process. Together with the visual impacts of the visual-range-filling hemispherical projection, this haptic feedback provides a holistic impression for the user.

The motion feedback induced to the passenger's perceptual organs is directly depending on the path and motion planning carried out on the real-time system. A huge variety of different parameters and perceptual limits can be exploited to increase the immersion of a passenger into the simulated environment, holding the capabilities for future research. A washout filter implementation specifically applied to the robot axes in favour of the Cartesian filter implementation will lead to a more efficient workspace utilization. Hence, specific feedback channels can be prioritized (e.g. lateral motion) leading to an enhanced motion perception, while simultaneously reducing the risk of motion sickness.

With the presented approach, GIS, VR visualization, simulation and haptic feedback are merged together, delivering added value for each of these fields. In geodesign processes, this combination provides a foundation for information exchange between the different roles. The VR system allows an intuitive and immersive visualisation of the planned concepts and therefore provides access to the displayed information for every role without the necessity to learn and understand special drawings or the symbolic language of other roles.

Applications for this integrated solution with a robot-based motion simulator or a Stewart/Gough platform range from city visualizations including virtual city tours and presentations including cars or helicopters to simulations like the presented wood harvester and Virtual Testbeds in multiple areas of engineering. With the 4D support, change visualisations of larger landscapes become possible.

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Applications of GIS in landscape design research

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Abstract

Despite its widespread availability there is evidence that GIS is underused in the realm of landscape design research. Though recognized as a useful tool for mapping and planning, the potential of GIS is often still underutilized due to a lack of awareness and prejudice. This paper explores some concepts of GIS-based analysis which link to the very heart of landscape architecture in a natural and intuitive way. Hence the possibility to break down barriers of using GIS in landscape architecture this paper aims to put forward some characteristic principles of study and practice that can be made operational via GIS while cultivating spatial intelligence in landscape design through exploiting its powerful integrating, analytical and graphical capacities. In this respect educational and research institutions have an important role to play, they must take the lead in knowledge acquisition on GIS-applications and passing it on, contributing to the academic underpinning and development of a digital culture in landscape architecture.

KEYWORDS

GIS; Landscape design research; Principles landscape architecture; Design knowledge

1. INTRODUCTION

Despite its widespread availability there is evidence that GIS (Geographic Information Systems) is underused in the realm of landscape architecture and related disciplines (Drummond & French, 2008; Göçmen & Ventura, 2010). Though recognized as a useful tool for mapping and planning, the potential of GIS is often still underutilized due to a lack of awareness and prejudice. This paper aims to put forward some important concepts of GIS-based analysis which link to the very heart of landscape architecture in a natural and intuitive way. Hence the possibility to break down barriers of using GIS in landscape architecture this paper aims to put forward some characteristic principles of study and practice in landscape architecture which can be made operational via GIS while cultivating spatial intelligence by means of geo-information technology. Here the focus is on applications of GIS in landscape design research – investigating landscape designs to understand them as architectonic compositions (architectonic plan analysis) (Steenbergen et al., 2002). By exploring landscape architectonic compositions with GIS, design knowledge can be acquired useful in the creation/refinement of a new design (Nijhuis, 2014 & 2015). Like other tools, such as microscopes and telescopes, GIS can help landscape architects to see what cannot be seen by the naked eye, realistically simulating past, present and future situations or superimposing information for means of analysis.

The next section addresses landscape design research and its principles of study and practice, followed by a brief discussion on why GIS is underused in the field. The next section elaborates on how these principles can be made operational through GIS-applications in landscape design research. The paper closes with some concluding remarks.

2. LANDSCAPE DESIGN RESEARCH

Landscape architecture is according to the International Federation of Landscape Architecture (IFLA): “A profession and academic discipline that employs principles of art and the physical and social sciences to the processes of environmental planning, design and conservation, which serve to ensure the long-lasting improvement, sustainability and harmony of natural and cultural systems or landscape parts thereof, as well as the design of outdoor spaces with consideration of their aesthetic, functional and ecological aspects” (Evert et al., 2010, p. 509). Within this broad definition there are three main areas of activity: landscape planning, landscape design and landscape management (Stiles, 1994; Thompson, 2008). These activities overlap and address different spatial levels of scale with different degrees of intervention. They require a multi-layered understanding of landscape regarding its spatial structure, development over time, the relational context, as well as the ecological, economic and social processes involved. Hence, over time a repertoire of principles of study and practice typical for landscape architecture has been developed to understand landscapes as (1) three-dimensional construction, (2) history, (3) scale-continuum, and (3) process (Nijhuis, 2013; cf. Prominski, 2004; Marot, 1995). These principles and their interplay are considered to be characteristic for landscape architecture and are embedded in theories, methods/process and products of design; landscape architecture's body of knowledge.

Particularly the products of design – landscape architectonic compositions – embody a great wealth of design knowledge regarding the application of the principles. Landscape architectonic compositions carry knowledge about how to satisfy certain requirements, how to perform tasks, and it is a form of knowledge that is available to everyone (cf. Cross, 2006). The concept 'composition' refers to a conceivable arrangement, an architectural expression of a mental construct that is legible and open to interpretation. In that respect the landscape design is regarded as an 'architectonic system' by which rules of design common to all styles are established (Colquhoun, 1991; Steenbergen et al., 2002). By studying landscape architectonic compositions landscape architects can acquire knowledge of the possible relationships between conceptual thinking and the three-dimensional aspect (Steenbergen & Reh, 2003). Landscape design research is a vehicle to acquire knowledge of spatial composition via architectonic plan analysis. It is a matter of developing and deploying spatial intelligence, the architectural capacity or skill to think and design in space and time (Gardner, 1999). In short: understanding is the basis for intervention. This implies that landscape design research is at the core of landscape architecture. But how can GIS be used in landscape design research?

3. GIS AND LANDSCAPE DESIGN RESEARCH

The uptake on using GIS is remarkably slow in landscape architecture, and when utilised it is often restricted to the basic tasks of mapmaking and data access. There still appears to be a lot of confusion regarding the use of the tool. Surveys show that the complexity and the wide range of possibilities of the software, as well as access to and availability of data are important factors in the neglect of GIS in landscape architecture (cf. Drummond & French, 2008; Göçmen & Ventura, 2010; for more backgrounds see Nijhuis, 2015). Scholars and practitioners in general are also not aware of the full potential of GIS in landscape architecture, particularly landscape design research. Another reason is that GIS is usually introduced not by need or demand, but by the mere possibility of using the novelty program. The effect of the use of GIS is thus largely up to the individual users who have a special interest in the technology, while combining it with skills in landscape architecture. Therefore, aside from training and data issues, a lack of knowledge of the possibilities of GIS in landscape architecture appears to be a significant barrier preventing greater use of GIS.

Knowledge development and dissemination of applications of GIS in landscape architecture are key factors in the awareness of the potential of GIS. A brief literature survey, spanning the period 1990-2013, exemplifies the observation that knowledge development and dissemination are lagging behind in comparison with landscape architecture or GIS as autonomous fields (respectively 16,220 and 61,000 references; Table 1) (Nijhuis, 2015). When combining landscape architecture and GIS, the query only brought up 187 references; 1.15% of all landscape architecture references in that period (Table 1).

KEYWORDS	N-PUBLICATIONS		KEYWORDS	N-PUBLICATIONS	
landscape architecture	3,840		landscape architecture, GIS	9	0.23%
landscape planning	3,510		landscape planning, GIS	89	2.50%
landscape design	5,300		landscape design, GIS	26	0.49%
landscape management	3,570		landscape management, GIS	63	1.70%
total	16,220	100%	total	187	1.15%
KEYWORDS	N-PUBLICATIONS		KEYWORDS	N-PUBLICATIONS	
GIS	61,000				
urban planning	15,200		urban planning, GIS	429	
urban design	10,900		urban design, GIS	149	

Table 1. Literature research based on title keywords, 1990-2013.
(Numbers based on analysis by Google-Scholar and Scopus using key phrases in the title of indexed publications, accessed: 27th February 2013. For Google-Scholar the operator 'allintitle:' is used.)

As indicated by the survey it is important to develop and disseminate knowledge of GIS-applications in landscape architecture. This will stimulate the use of the tool by the mere possibility of 'following' the discipline and developing aspects of it, and by setting in motion fundamental developments in the field. In particular for landscape design research as a core activity there is a lot to gain. The assumption is that GIS can enrich procedures of investigation and analytical techniques in landscape design research providing alternative readings of landscape architecture designs.

4. GIS-APPLICATIONS IN LANDSCAPE DESIGN RESEARCH

The application of GIS in landscape design research is here understood as an extension of the fundamental cycle of observation, visual representation, analysis and interpretation in the process of knowledge acquisition, with alternative visualisations and digital landscape models as important means for this process (Nijhuis, 2015). Using the calculating power of computers, combined with inventive modelling, analysis and visualisation concepts in an interactive process, opens up possibilities to reveal new information and knowledge (Figure 1).

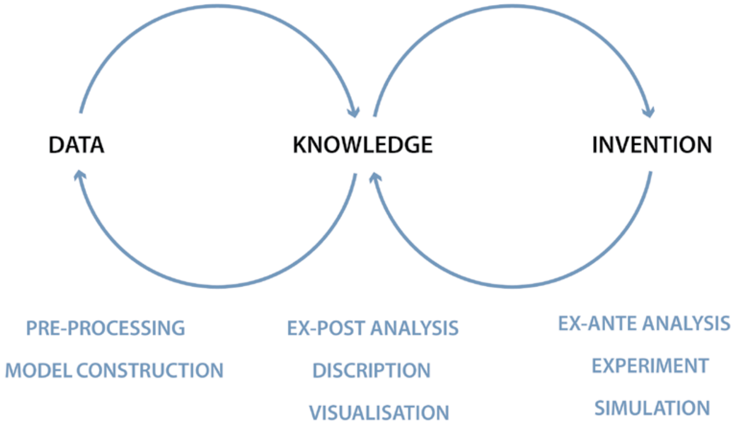

Figure 1: GIS as a facilitator and mediator in the knowledge formation-cycle and design generation-cycle: an iterative process from data to knowledge, from knowledge to invention (source: Nijhuis, 2015).

As such can GIS be regarded an external cognitive tool that facilitates and mediates in design knowledge acquisition. GIS facilitates in the sense that it can address the ‘same types of design-knowledge’ regarding aspects of the landscape architectonic composition, but in a more precise, systematic, transparent, and quantified manner. GIS mediates in the sense that it influences what and how aspects of the composition can be understood and therefore enables design researchers to generate ‘new types of design-knowledge’ by advanced spatial analysis and the possibility of linking or integrating other information layers, fields of science and data sources.

There are at least three operations in which GIS could be useful for landscape design research exploiting GIS in its powerful integrating, analytical and graphical capacities (Nijhuis, 2015):

- GIS-based modelling: data acquisition and the description of existing and future landscape architectonic compositions in digital form;

- GIS-based analysis: exploration, analysis and synthesis of landscape architectonic compositions in order to reveal latent architectonic relationships, while utilizing the processing capacities and possibilities of computers for ex-ante and ex-post simulation and evaluation;
- GIS-based visual representation: representation of (virtual) landscape architectonic compositions in space and time, in order to retrieve and communicate information and knowledge of the landscape design.

These operations have a great potential for measurement of relevant and new aspects of landscape architectonic compositions, as well as offering an alternative ways of understanding them. In particular while using the typical principles of study in landscape architecture as a point of departure for computer-aided architectonic analysis a 'toolbox' emerges for GIS-based landscape design research. This toolbox consist of a set of GIS-analysis methods and techniques stratified according the typical principles of landscape architecture. In that way concepts of GIS-based analysis can be linked and deployed in accordance with the experience of landscape architects.

4.1 Understanding landscape architectonic compositions as three-dimensional construction

In this principle the focus is on GIS-applications for exploring the landscape architectonic composition 'from the inside out', as it could be experienced by an observer moving through space using concepts of GIS-based visibility analysis (e.g., viewsheds, isovists) and virtual 3D-landscapes. Here GIS is employed to explore the visual manifestation of open spaces, surfaces, screens and volumes and their relationships in terms of structural organisation (e.g., balance, tension, rhythm, proportion, scale) and ordering principles (e.g., axis, symmetry, hierarchy, datum, transformation) (cf. Bell, 1993). The basic premise is that the shape of space, plasticity (form of space-determining elements) and appearance (e.g., colour, texture, lighting) of spatial elements in the composition determine the relation between design and perception. GIS-based landscape design research addresses the form and functioning of three-dimensional landscape space, which creates a certain spatial dynamic. Here GIS is employed to describe and evaluate volumetric characteristics of landscape architectonic structures, scenography and movement, the treatment of the panorama, or development over time. In this way the framing of a landscape or urban panorama, or the construction of a spatial series along a route, making a pictorial landscape composition, can be studied further (Figure 2).

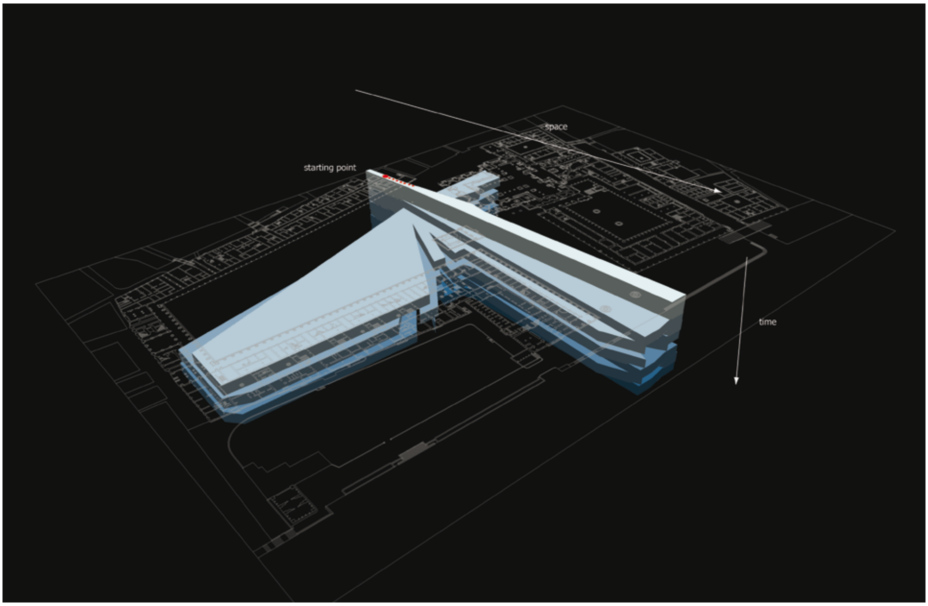

Figure 2: GIS-based visibility analysis in which successive fields of vision are calculated from the entrance to Piazza San Marco, Venice (Italy). Known as a Minkowski model, it shows from top to bottom how the square 'unfolds' – from a tightly framed view of the water to a view of the entire square (source: Nijhuis, 2014) .

4.2 Understanding landscape architectonic compositions as history

GIS-applications focus on 'reading' the landscape as a biography, as a palimpsest that evidences all of the activities that contributed to the shaping of that landscape. Here the landscape architectonic composition is regarded as a layered entity where traces that time has laid over can reinforce or contradict each other. Knowledge of these layers is one of the starting points for new transformations of the composition involved, or adding a new design layer. This principle involves the evolution of the composition over time and investigates operations of 'erasing' and 'writing' history (Lukez, 2007). Operations of erasing history include: complete or partial eradication, etching, excision, entropy and excavation. Operations of writing history include: parcelling, infill, addition, absorption, enveloping, wrapping, overlay, parasitize and morphing. Here GIS is employed to get to know the historical situation and the development of the composition via time-slice snapshots. Via the construction of GIS-based virtual historical landscapes of a certain time-slice snapshot or comparisons of several of them (via overlay, attributes or in a series) the dynamics and change over time can be explored (Figure 3).

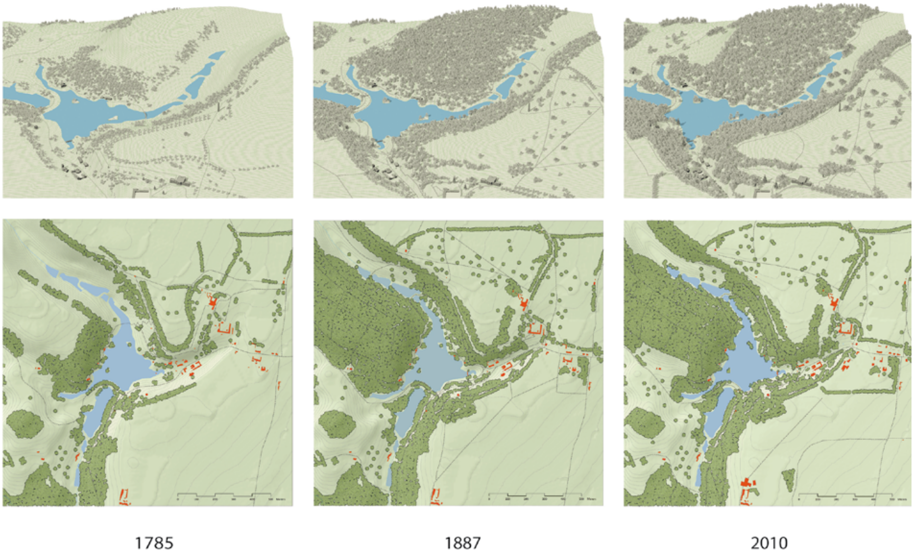

Figure 3: GIS-based reconstructions of Stourhead landscape garden (Wiltshire, UK) in different time stages of its development represented as virtual 3D landscapes and maps (source: Nijhuis, 2015).

4.3 Understanding landscape architectonic compositions as scale-continuum

In this principle the focus is on GIS-applications addressing the landscape architectonic composition as being part of a scale-continuum. The level of scale of a composition under study is important, because any size larger than that of the study area supposes a 'larger context', but any size smaller than that of the smallest detail supposes context as well (De Jong, 2006). The composition is considered to be part of a relational structure connecting scales and spatial, ecological, functional and social entities. GIS-applications focus on exploring topological (vertical) and chorological (horizontal) relationships, the embedment of a specific site or location into the broader context at different scale levels. Here spatial patterns are studied by map dissection (selection and reduction) as a basis for spatial association analysis, which explores the relation between different patterns. Techniques for spatial association analysis are overlay analysis and cross-reference mapping. Here GIS is employed to explore for instance the position of the designed landscape in its natural, cultural or urban context on multiple scale levels (Figure 4).

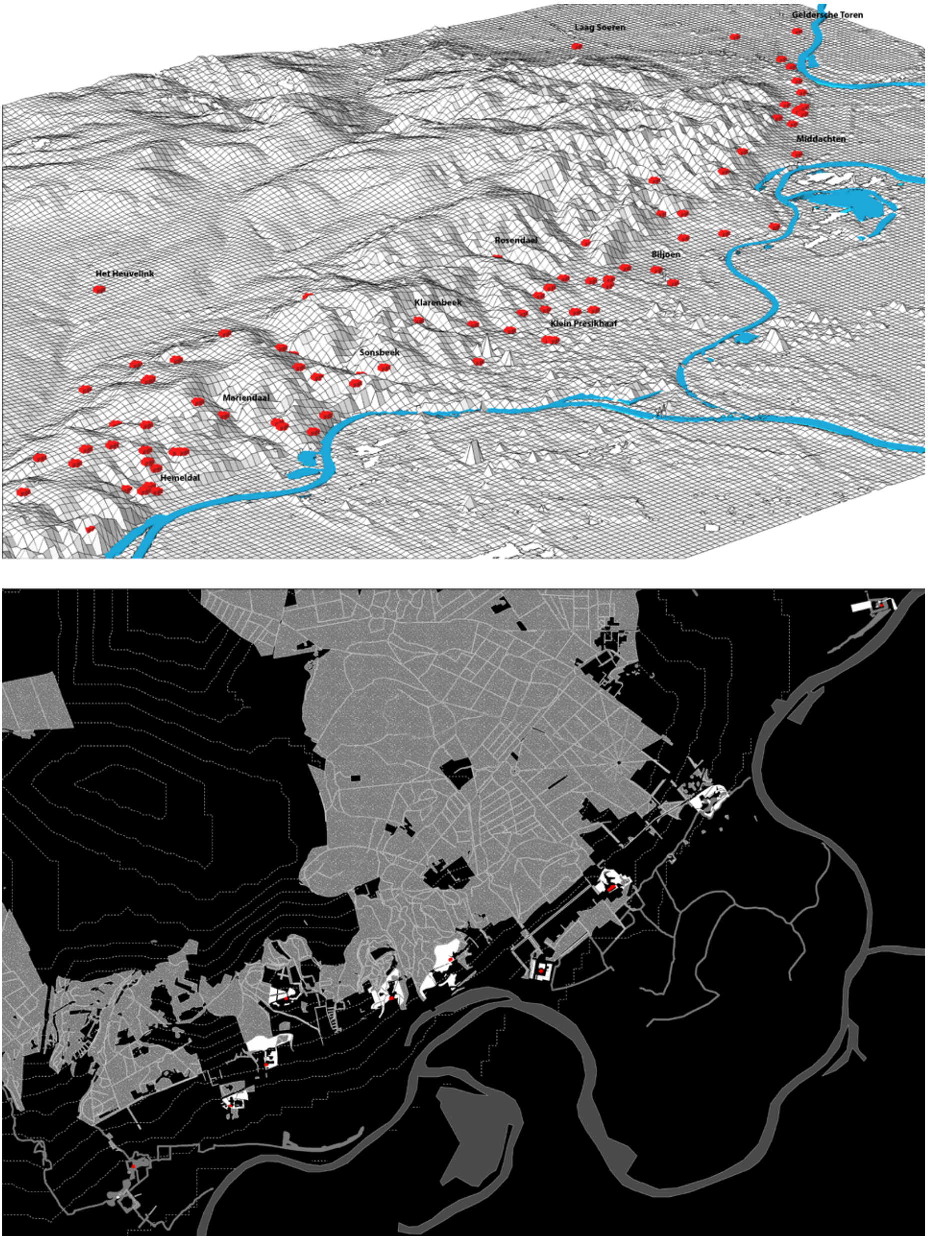

Figure 4: GIS-based spatial association analysis of the distribution and allocation of historical estates of Guelders Arcadia (near Arnhem, Netherlands) in the natural landscape dominated by the ice-pushed ridges of the Veluwe-East (top) and analysis landscape architectural compositions of selected individual estates which show a remarkable sensitivity towards natural conditions at multiple scale levels (source: Nijhuis, 2016).

4.4 Understanding landscape architectonic compositions as process

GIS-applications focus on the interaction between landscape processes and typo-morphological aspects and address aesthetic, functional, social and ecological relationships between natural and human systems. The landscape architectonic composition is regarded to be part of a holistic and dynamic system of systems as an expression of the interplay between formal aspects and interaction between ecological, social and economic processes (Zonneveld, 1995). The composition is considered as an ongoing process rather than as a result. Natural and social processes constantly change compositions, making the dynamics of the transformation a key issue in research and design. Here GIS is employed to understand the landscape as a system employing geo-computational models (deterministic or stochastic) such as morphological models exploring the social logic of space, or ecological process models investigating the spatial development and expression ecosystems (Figure 5). Also time-geographic models, traffic and transport models, planning models, economic models, cognitive models, multi-actor models, building technology and logistical models, hydraulic engineering models, nature and environmental models, agricultural models, energy models are of use. Spatial association analysis and (automatic) construction of virtual 3D landscapes are useful analytical operations.

5. CONCLUSION

The here briefly discussed toolbox for GIS-based landscape design research is not about presenting new GIS-analysis methods and techniques. It rather re-presents or frames useful GIS-concepts from the perspective of landscape architecture. Hence, this toolbox embodies a way of thinking typical for landscape architecture which is visible in landscape architecture theories, planning and design processes and products. It offers the possibility to link concepts of GIS-based analysis to the very heart of landscape architecture in a natural and intuitive way in the hope to break down barriers of using GIS in landscape architecture. The typical principles of landscape architecture can also serve as a basis for cultivating spatial intelligence by means of geo-information technology while raising awareness and take away prejudice.

Studies such as Nijhuis (2015) point out that GIS can extend the design researchers' perception via measurement, simulation and experimentation, and at the same time offer alternative ways of understanding the landscape architectonic composition. This offers possibilities of exploring important aspects of landscape design research, such as the visible form and kinaesthetic aspects, analysing the composition from eyelevel perspective.

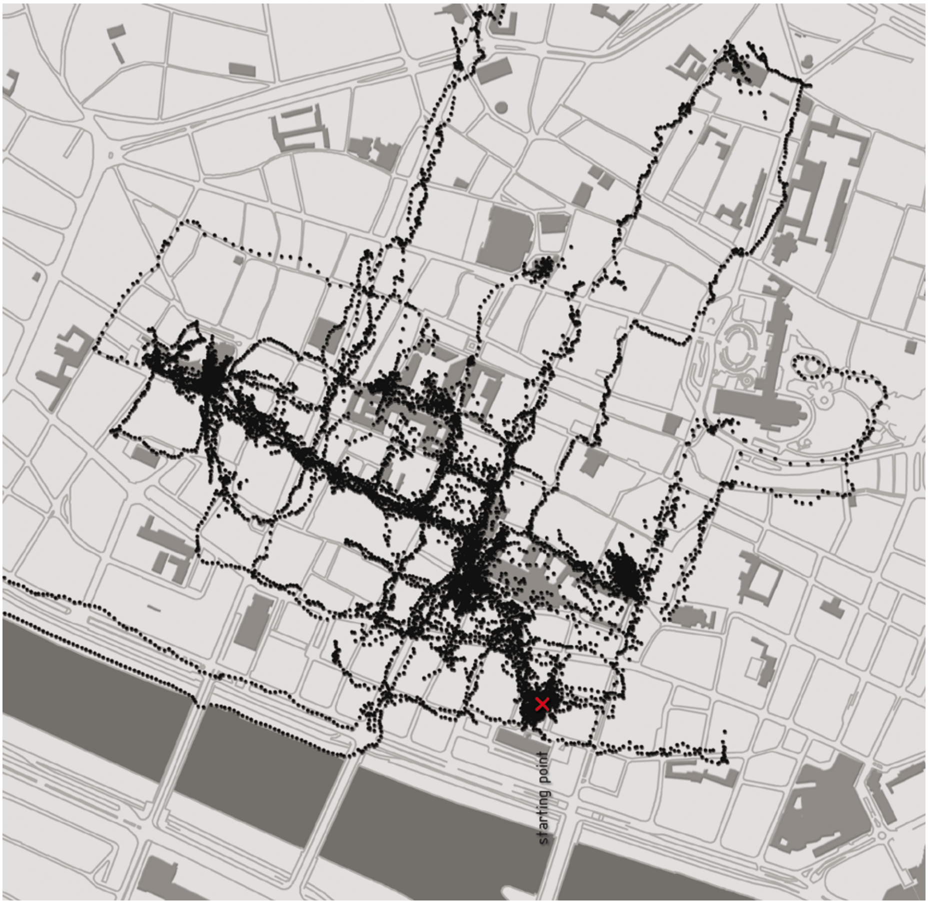

Figure 5: GPS-monitoring of pedestrian movement by tourists in Rouen (France). In order to reveal their movement behaviour several dozens of tourists were asked to carry GPS-devices while visiting the town centre, here represented as a map
(source: Nijhuis, 2015)

GIS has the potential to measure phenomena that are often subject to intuitive and experimental design, combining general scientific knowledge of, for instance, visual perception and way-finding, with the examination of site-specific design applications. GIS also enables one to understand landscape architectonic compositions as a product of time, via the analysis of its development through reconstruction and evaluation of several crucial time-slice snapshots. As such GIS-based landscape design research can serve as a basis for the academic underpinning and the development of a digital culture in landscape architecture exploiting GIS in its powerful integrating, analytical and graphical capacities. Educational and research institutions have an important part to play, they must take the lead in inspiring students and practitioners, building up their knowledge and passing it on, and adding new tools to the traditional craftsman’s toolbox.

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From Metaplanning to PSS 2.0

Exploring the architecture of Geodesign as a process

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Abstract

This paper explores the perspective of geodesign as a process. As such, it is argued methods and tools are needed to manage the process complexity, including the definition of the involved parties, of their roles and responsibilities, as well as all the steps to be undertaken to unfold the process, together with their underlying methods and enabling technologies and tools. A metaplanning operational approach based on Business Process Management is proposed to deal with the process complexity and eventually as a means to support the construction of a second generation of process-oriented Planning Support Systems. The overall discussion is supported by practical examples aiming at demonstrating how the Business Process Modelling and Notation language can be used to represent the planning processes from high level overview models to detailed ones which can express geodesign methods and enabling technologies.

KEYWORDS

Metaplanning; Geodesign; Planning Support Systems; Business Process Management; Planning Process Modelling

1. INTRODUCTION: GEODESIGN AS A PROCESS

Since the last decade, the concept of Geodesign has been attracting growing attention of scholars and practitioners worldwide as a way to achieve more sustainable spatial planning and design practices. While several definitions of Geodesign have been given, many of them refer to a process – not necessarily but most likely based on extensive use of (spatial) information technologies – which would enable environmentally sustainable collaborative design and decision-making in the governance of the territorial evolution, limiting the possible negative impacts on the communities and the territories. In most of the definitions, as the name recall, the focus is on the design part of the governance process, which, depending on the scale, may correspond to the creation of spatial plans (e.g. regional planning, local land-use planning, or large-scale development project design).

Much research have been devoted to formalise methods and enabling technologies for the implementation of Geodesign in practice and a growing number of case studies can be found documented in literature (McElvaney, 2012). However, less research attention has been devoted so far to study Geodesign as a process, with the notable exception of the Steinitz's framework (2012). Indeed the framework entails the perspective of Geodesign as a process consisting of three iterations along which six models are envisioned, designed, and implemented, with the final aim of constructing a spatial plan or design, depending on the scale. The six models are used to represent, study, and evaluate on-going territorial processes, and to design possible change scenarios, to analyse their impacts, and eventually to create consensus about which scenario among them should be implemented. While the Steinitz's framework may offer a general outline of the main steps which should be carried on within a geodesign study, and it may be valuable in guiding a geodesign team in defining how to develop the six models, the latter should be detailed by the participants in each contextual case.

Unlike it often happens in real world plan-making processes, where the role and the responsibilities of some or many of the participants may be not clearly defined, as well as the underlying workflow which drives it, and the method and tools to be used, Steinitz's framework for Geodesign requires in the second iteration to detail the working plan for the process, defining in reasonable details how the six models will be implemented in the third iteration. It should be noted that this definition may remain flexible and blurred, but still this should be a well-considered choice and a documented responsibility. Whatever underlying approach is chosen to inform the process, most recent communicative planning theories acknowledge the importance of driving the process according to a roadmap which may be understood and accepted by those involved, and possibly changed along the way if needed (Healey, 1993). Hence, in order to enhance the communicative rationality of the planning process methods and tools for ensuring its comprehensibility, integrity, legitimacy and trustfulness should be put in action. To address these issues, an operational approach to metaplanning is proposed in this paper.

2. FROM METAPLANNING TO PROCESS-ORIENTED PLANNING SUPPORT SYSTEMS

In broad terms metaplanning can be defined as the design of the planning process. Spatial planning in general, and Geodesign as specific way to design spatial plans, involves a sequence of activities to which a different set of actors may participate. Actors, which may include decision-makers, planners and other experts, as well as other stakeholders, and in some cases the wider public, may play different roles and perform different tasks within the same or different activities. Performing a task may require the implementations of different methods, the application of different (analogue or most likely digital in the case of Geodesign) tools, and different ways of processing information to produce knowledge and make decisions. As such, plan-making can become a fairly complex process which should be appropriately managed; the objective is to achieve awareness and mutual understanding among the actors on the procedural workflow as well as on the purposes, the objectives, and the outcomes of each activity, and of the overall process. Thus, metaplanning should be intended as a preliminary design step which returns an agreed ‘to-be’ model to be used for the management of the planning process. Such model should be as flexible as to be iteratively updated along the process life-cycle, if needed.

Often in spatial planning (e.g. Regional Planning or Local Land Use Planning), no or little attention is paid to concept of metaplanning, and in such cases taming complex multi-actors planning processes and procedures may be confusing. A lack of common understanding among the actors may arise, implying difficulties in collaboration and in reaching consensus; understanding how, why, when, by whom planning decisions are made, may result in being unclear to both the internal participants and the external observers. The latter should be considered not a minor pitfall as both propositions from advances in planning theory (Healey, 1993; Innes, 1996; Khakee, 1998) as well as binding regulations on Strategic Environmental Assessment (SEA) require to evaluate, explain and document not only the product (i.e. the final plan) but also the process of plan-making.

Although not as commonly acknowledged as one might expect, the importance of metaplanning has been advocated in several disciplines spanning from artificial intelligence (Bhargava et al.,1997), to management science (Emshoff, 1978), to spatial planning (DeBettencourt et al.,1982). According to Bhargava et al. (1997) a metaplanner can be defined as a computational program which, when executed, produces a plan of actions. In a similar vein with regards to spatial planning, metaplanning can be defined as a design process which produces a plan of the (plan-making) process. With more specific regards to urban and regional planning, DeBettencourt et al. (1982) claimed that metaplanning as a structured process for constructing both responsive as well as ethically sound approaches to planning should be integrated into the planning function to increase its usefulness and viability.

Central to the operational implementation of the concept of metaplanning is the description of the planning process. Several attempts have been proposed by scholars to formalize the description of the planning process for diverse purposes (McLoughlin, 1969; Hall, 2002), however these results appear not to have much affected either the planning practices or the design of a Planning Support System (PSS). The latter implication is not of minor relevance, for a PSS in broader terms represents information systems which support the planning process. As an information system, a PSS should integrate all the enabling technologies for a given workflow, implement Geodesign methods and techniques, and offer all the data resources, the interfaces and the processing tools to support the different actors which take part in the process activities. Thus the definition of the process and the Planning Support System architecture should be strictly tied, and the latter should be derived from the model of the process workflow. Indeed, undoubtedly, limitations in current PSS diffusion may be addressed to lack of flexibility and of adaptability to contextual planning process settings, showing an implementation gap between planning research and practice.

The first generation of PSS were developed in the last two decades or so on the base of the seminal model proposed by Harris (1989) as computer systems able to integrate sketch planning, GIS and spatial models as well as visualization tools to support the planning functions. Notwithstanding the success of several implementations such as What-if? (Klosterman, 1999), Criterion Planners’ Index (Allen, 2001), or Placeways’s Community Viz. (Kwartler and Bernard, 2001) still this first generation of PSS, or PSS 1.0, faced limited diffusion in the planning practice. Indeed if we make reference to the Steinitz framework many of them may be used to implement a specific part of the process within the process, the evaluation or the impact models, none of them alone is fully able to support the overall process along the six models and the three iterations. Hence, a change in PSS design perspectives would be required.

According to Champlin et al. (2014), PSS design should be seen as a socio-technical process involving their users. Likewise it is argued here that PSS design should be process-driven, rather than methods- or technology-driven, and since metaplanning concerns the design and formalisation of the actual planning process, metaplanning should also inform the design of the information systems for planning support.

To address this challenge, Business Process Management methods and tools have been applied by the author to implement the metaplanning concept in the urban and regional planning, and SEA domain, aiming at demonstrating that metaplanning may both improve the process and ease the customization of PSS development accordingly: together the latter results entail the concept of a second generation PSS, or PSS 2.0. Hence in this contribution, the author proposes the concept of metaplanning as a formal step to be introduced at the head of the planning and design process, and proposes as original method for its practical implementation the application of Business Process Management (BPM) techniques. The resulting process orientation in PSS 2.0 not only would allow the flexible integration of Geodesign, enabling technologies for implementing the first five Steinitz' frameworks models – i.e. representation, process, evaluation, change and impact (Steintiz, 2012) –, but would also support the management and the evaluation of the decision model, that is the workflow through which decisions are made in the three iterations.

3. IMPLEMENTING METAPLANNING WITH BUSINESS PROCESS MANAGEMENT: BUILDING THE FRAMEWORK

In line with the above assumptions, metaplanning consists of the task of specifying actors, activities, methods, tools, inputs and outputs, workflows, or, in other words, the ex-ante iterative and adaptive design of the planning process. Metaplanning should start at the very beginning of the process and accompany it until the end of its implementation, starting with the proposition of draft 'to-be' process models, and following with their consolidation and monitoring along the process life-cycle. For the sake of clarity and to avoid unnecessary complexity, it is assumed here that the process lifecycle starts with the decision to make a plan and ends with the adoption of the plan by the relevant authority. In metaplanning, the process models should firstly be used to achieve consensus on how to proceed and to carry on the activities, then to coordinate the collaboration among all the participants, or actors, and eventually to document how the process developed, which for several respects is a due product within the Environmental Report in the SEA of a spatial plan.

If the aims of metaplanning are both the improvement of the process and of its outcomes as well as its management and implementation, hence the needs arise for a representation language which can describe the process with regards to its components and to their relationships, and for a technology framework able to support the integration of the necessary tools into process-oriented PSS.

Business Process Management (BPM) offers both methods and technical tools which can be used for metaplanning operational implementation, in spatial planning in general, and in Geodesign more specifically, given the extensive use of Information Communication Technology (ICT) tools. BPM includes concepts, methods and techniques to support the design and analysis, as well as the administration, the configuration, the enactment of business processes (Weske, 2012). In general, the success of the emerging field of BPM is due to the facts that it may both support the improvement of the processes offering design and analysis tools (i.e. business perspective), while at the same time it can also support the integration and deployment of the enabling technology (i.e. IT perspective). Many Business Process Management Systems (BPMS) have been developed in the last decade to enable business processes design, analysis, configuration and enactment on the base of explicit process model representations. Indeed, the basis for BPM is the explicit representation of processes, or process models, with their actors, activities and execution constraints among them.

Hence the opportunity to investigate to what extent the BPM approach can be applied to urban and regional planning processes. Indeed as demonstrated later in this paper, process models can be built to describe the planning process in terms of its constituting elements including actors, activities, workflows, as well as data sources and processing tools. To this end, Business Process Model and Notation (BPMN) thanks to its rich semantics can be used as a standard graphical notation for representing planning processes and sub-processes in form of diagrams.

In BPMN the process participants or actors are represented as pool and lanes; the activities are represented as tasks or sub-process, which can be carried on with or without the support of ICT services or tools. Moreover a variety of executions constraints including gateways, message flows, and other events can be used to coordinate the workflow execution. Although BPMN is not primarily designed for data modelling, still it offers a set of notations that allows modelling the data involved in a process. Moreover, BPMS manage external data sources used as input or output of the activities such as documents, data tables or spatial data layers, and other internal data and parameters used to configure the workflow execution, such as the involved actors' addresses or preferences information.

A major advantage of BPMN is that it is both a human- and machine-readable language, so that it can be used by humans in a socio-technical metaplanning exercise to define the process, and by BPMS to enact the process, that is to orchestrate the ICT services integration to support the various planning tasks. The latter capability is enabled by process configuration, when settings are defined in a BPMS to invoke external digital data (e.g. standard Web Feature/Coverage Services, or W F/C S) and processing services (e.g. standard Web Processing Services, or WPS) when a task is executed by the BPMS workflow engine. Most of the off-the-shelf BPMS feature a BPMN diagram editor for design and analysis, a repository where models are collected, and a process engine which orchestrates the integrated execution of services and serve them to the relevant actor interfaces to support the implementation of planning tasks at run time. In the remainder, some simple planning process examples are presented as proof of concepts, aiming at demonstrating the reliability of BPMN to build planning and geodesign process models, which can be used in metaplanning and may constitute the core of the approach on the base of which the paradigm of process-oriented second generation Planning Support Systems, or PSS 2.0, can be implemented.

4. METAPLANNING IN PRACTICE: TOWARD SECOND GENERATION PSS

As introduced in the previous section, planning process modelling is proposed here as main tool for implementing metaplanning in practice. As a first simple example to show planning process modelling with BPMN, let us consider the following excerpt from Khakee (1998, p. 364) describing a general Rational Comprehensive Planning (RCP) process model in natural language:

> *"The rational planning [...] is based on instrumental rationality, whereby decision-makers decide on goals and put questions about policy measures to professional planners and other experts who then formulate alternative plan proposals."*

This very high level description of a RCP process may apply to a number of real world processes. Needless to say, a planning process might assume many other very different forms in practice, which in this case will be modelled accordingly. Anyway, the RCP process description in natural language specifies a number of actors, activities, a sequence flow, inputs, and outputs of the process.

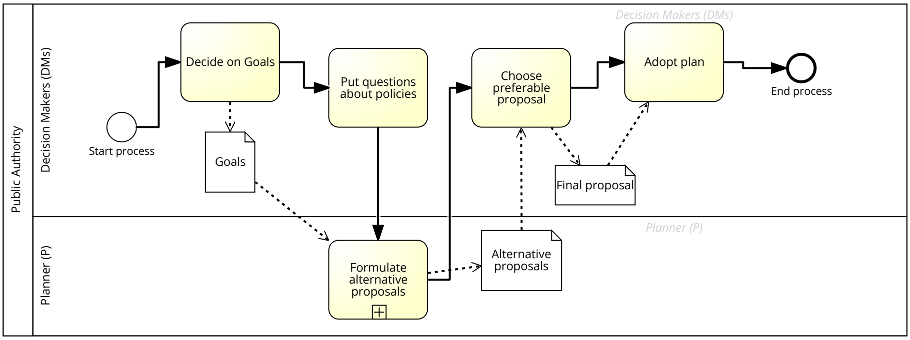

Figure 1. Planning Process Model of a generic Rational Comprehensive Planning process (as in Khakee, 1998, p. 364) represented in Business Process Model and Notation language (BPMN 2.0).

The Planning Process Model (PPM) shown in Figure 1 represents the same process in BPMN. More precisely, with some additional information, it shows how the process is carried on by a public authority (i.e. the pool) within which the two main roles or actors, the planner 'P' and the decision-makers 'DMs' (i.e. the lanes) perform their activities or tasks (i.e. rounded rectangles). Data or documents (i.e. rectangles with folded corner) can be input or output for certain tasks. The high-level process representation can be further detailed using sub-processes (i.e. rounded rectangles with '+' sign). The diagram in figure 2 shows a possible sub-process – among the many which could be chosen – which can be executed to unfold the 'Formulate Alternative Proposals' activity.

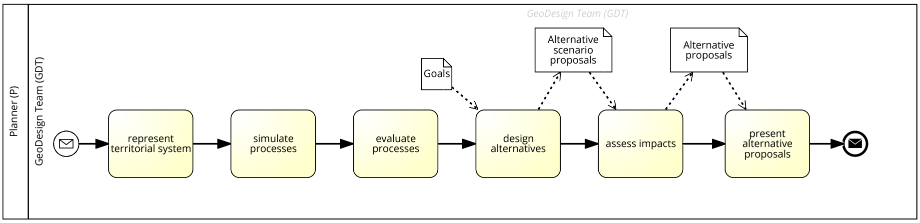

Figure 2. Representation of a sub-process of the RCP process model (see Figure 1) in BPMN 2.0.

In the example, the 'Formulate alternative proposals' activity model (Figure 2) recalls the workflow of a Geodesign study involving the creation of representation, process, evaluation, change, impact and decision models (Steinitz, 2012).

The sub-process decomposition can be further detailed until elementary tasks are defined. Thus, process modelling can describe the planning process down to the finest details.

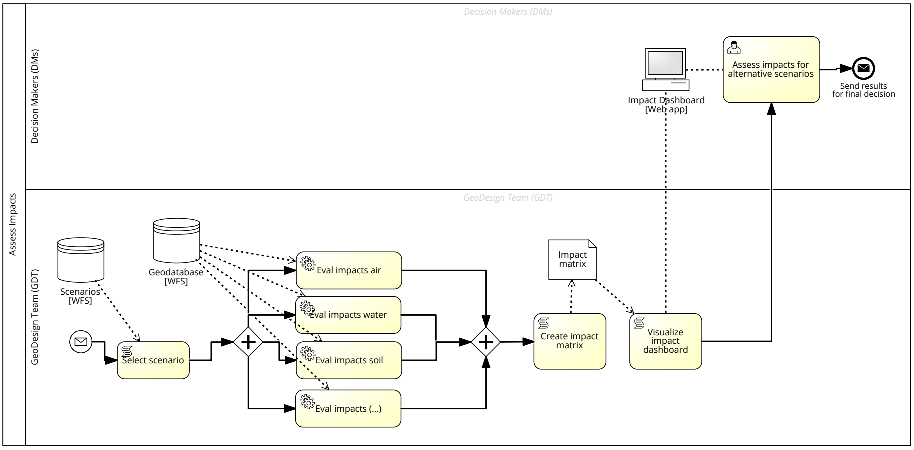

Figure 3. Decomposition of a sub-process of the RCP process model in BPMN 2.0.

In figure 3, the 'assess impacts activity' is further decomposed. Together with actors, activities, and gateways which describe the sequence flows, data objects (i.e. standard Web Feature Services) and other artefacts (i.e. an impact dashboard web app) are shown in this example sub-process model. As by the model, after alternative scenarios are built in the 'design alternatives' activity, a software script selects one by one each scenario from a database, and for each scenario a number of processing models available in a remote server as standard Web Processing Services (WPS) are run to evaluate the scenario impact on air, water, soil and all the other natural and anthropogenic subsystems which may have been considered important by the participants. Afterwards, the results are saved and visualized for the decision-makers to make their assessments, which will be the base for the final decision.

The examples shown in figure 1 to 3, while depicting only one possible way by which a part of a planning process may unfold, show how the BPMN language may effectively represent the process elements needed to fully document both the activity workflows, the role of the actors, and the required enabling technologies.

Using light-weight BPMN web editors such as Signavio (www.signavio.com) or ProcessMapper (www.processmapper.com) process can be designed and analysed in order to avoid inconsistencies. Planning process models can be also created collaboratively and stored in repositories for sharing and reuse (e.g. in real world metaplanning exercises, for research purposes, for education and training exercises).

Moreover, with full-featured BPMS, the planning process models can be used for process-oriented second generation PSS deployment. Indeed, professional BPMS after configuration can automatically turn graphical process models into desktop or mobile applications. That is, with reference to the previous examples, when a task is instantiated, the BPMS can supply to the responsible users the necessary ICT services (e.g. desktop applications, apps, or even atomic web data or processing services) as demonstrated by Campagna et al. (2014a, b).

5. ONE MORE PRACTICAL EXAMPLE OF PLANNING PROCESS MODELLING

As one more example from a real-world planning process, this section proposes the Planning Process Model in BPMN of Geodesign workshop held in Belo Horizonte (BR) in 2015. The Geodesign workshop process was structured according to the Steinitz Framework for Geodesign (Steinitz, 2012) and was supported by the Geodesign Hub PSS (http://www.geodesignhub.com/). The workshop was coordinated by a team led by the author (i.e. the Coordination Team), and a group of 21 academics, students and public administration officials participated, representing the local stakeholders. The schedules lasted three days within which the participants were firstly introduced to the

Geodesign approach and to the PSS, and then carried on a collaborative conceptual design of future scenarios for the Pampulha urban region. The workflow was intense and the sequence of activities sometimes frantic under the pressure of tight schedules within the available time. From the organisational perspective documenting the process in BPMN beforehand was very helpful first to achieve mutual understanding among the Coordination Team and then to guide the group successfully towards the end, where three future final scenarios were chosen and presented by the participants. The base BPMN workflow of the Geodesign workshop is given in figure 4.

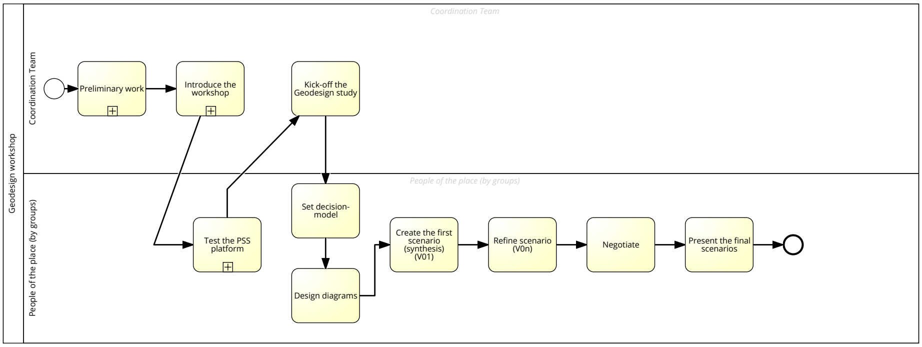

Figure 4. The main activities of the Geodesign workshop.

In the PPM depicted in Figure 4 all the main activities of the Geodesign workshop are given in sequence. Each of them can be further defined adding details about sub-tasks, data input/output of each activity, and supporting technology adopted. The sequence can also be described with a higher level of details as in Figure 5.

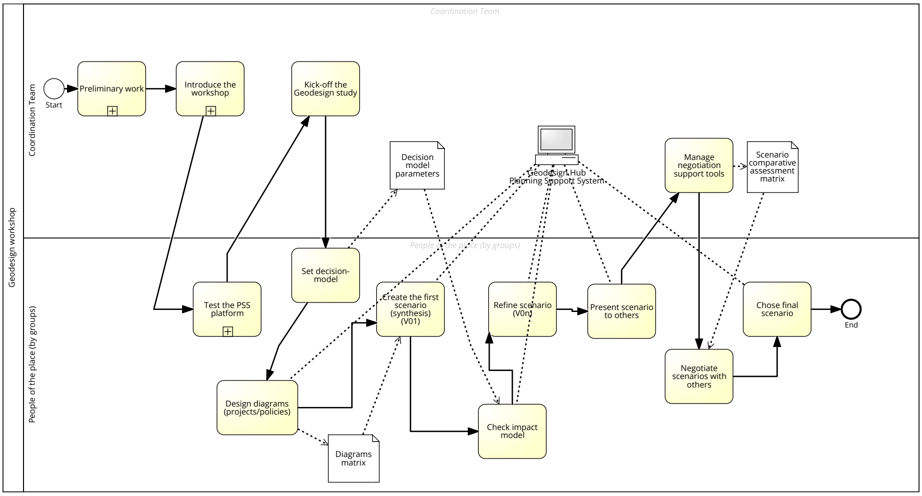

Figure 5. Detailed sequence of the Geodesign workshop.

Both of the PPM show just one possible way to implement the process and can be used as to-be or as-was model to guide or to document the process unfolding respectively. In both cases, planning process modelling contributes to develop a better understanding of the process among the participants with benefits for the coordination and the transparency.

6. CONCLUSIONS

As discussed in this paper, BPM methods and tools may offer several advantages for the implementation of metaplanning in practice. However, more research should be devoted to test the reliability of the BPM approach to metaplanning and PSS 2.0 design and implementation in complex real world planning processes.

On the opportunities side, it seems reasonable to expect that the use of BPMN as a semantically-rich graphical language to represent the planning process may be useful both for creating better mutual understanding among the process participants in the plan-making phase, as well as to make the process accountable to the community when the results are presented during the SEA information and consultations, or anytime after the plan adoption. 'To-be' planning process models in BPMN can also be used to share process templates, such as often happens with regional regulations which define specific actors and phases to be implemented in planning processes at the local level. To further demonstrate these opportunities more on-the-field research should be devoted to compare the communicative power of BPMN with other languages. However, unlike with texts, a process model in BPMN to be valid should have a start, an end, and a sequence flow of activity between them, making easier to detect bottlenecks, deadlocks, or any lack of definition which may undermine the effectiveness of the process instances. Early experiments carried on by the author on regional planning regulations and guidelines already demonstrated that the translation of textual process guidelines to BPMN may help to detect possible issues and pitfalls in the process definition which can prevent the achievement of mutual understanding among the different players in spatial government.

From an operational perspective, to put metaplanning in practice with BPM, especially in complex planning processes, the full representation of the process would require possibly a high number of models. However, well-structured repositories can be used not only to orchestrate the process, but also after its implementation to share plan-making knowledge. Thanks to a powerful query mechanism, model repositories could be used ex-post to understand how tasks were implemented and by whom. Such information would broaden the assessment of the decision-making process, which already should be part of SEA, but most of the time is limited to such issues as the reliability of data sources for decision-making. This way, not only the effect of data accuracy but also the way data are used to support decisions could be documented and evaluated ex-post. In addition, the planners and the other actors with their organisational roles and skills, as well as the methods and the enabling information technology landscape of the geodesign firm, can be represented accurately, and shared with other actors for re-use for professional, research or education and training purposes.

While it has been already demonstrated that simple routine planning tasks can be represented in BPMN, and that those models can be used to enact the automated orchestration of the supporting technology, it would be desirable that more empirical research would be devoted to understand to what extent it is possible to reach similar results and advantages in more complex planning activities, or eventually in the full planning process life-cycle.

Other underlying issues, which should be more deeply investigated, might also be related to how BPM may deal with possible informal characteristics of a planning process, and on the actual opportunity and willingness to make the planning process as structured as business processes in other domains.

To conclude, as concisely claimed in this paper, BPM method and tools can be used both to implement metaplanning with the aim of improving the planning process, and, at the same time, to deploy process-oriented second generation PSS. Indeed further research is needed to apply this approach to deal with the complexity of real world planning practices, and it should include both the business and the technology perspectives in order to bridge the gap between PSS research and practice, and eventually develop robust BPM platform for process-oriented PSS deployment. However the foundation seems to be already set to advance metaplanning implementation in practice and second generation PSS research.

ACKNOWLEDGEMENTS

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Integrating geodesign and game experiments for negotiating urban development

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Abstract

In this article we explore an expansion of geodesign to analyze processes of competition and cooperation by combining it with game-theoretical modelling and experiments. We test the applicability of facilitating these two fields in an integrated workshop by analysing the case study of oversupply of development sites in the Liemers corridor. Two workshops were held, with representatives of the six municipalities involved and with the regional and provincial authority, in which participants negotiated over the distribution of the supply of development sites. The workshops were performed around an interactive MapTable, with spatial information (from GIS) and financial information (from the game-theoretical model) being visualized in real-time. The integrated workshops were assessed to discover differences in terms of process and outcomes, and they examine whether and how learning takes place. We conclude that the combination of game theory and geodesign provides added value for planning support by facilitating a realistic discussion, and negotiation that is strongly connected to real-life locations, and by aiming at designing a common, collaborative solution. Through the integrated workshop learning about the problem of oversupply in financial and geographical terms and also about each other's motives and behaviour is stimulated.

KEYWORDS

Planning Support Systems (PSS); Geodesign; Spatial development; Collaborative planning; Negotiation game; Housing; Business areas

1. INTRODUCTION

After being widely introduced during the 2009 Annual ESRI International User Conference in San Diego, California, the concept of geodesign has attracted a lot of attention from different fields of study including geography, planning, landscape architecture, and environmental studies. The emphasis of geodesign has been on the entire design processes in geographical environments through stakeholder participation and collaboration with the aid of technology (Goodchild, 2010).

In this article we explore the application of an expansion of geodesign as an approach to analyse the cooperation and competition process among stakeholders by integrating the technique of spatial visualization with help of Planning Support Systems (PSS) with game-theoretical modelling and simulation in a workshop. We applied this approach in a case of regional planning with, at present, supply-led provision of sites for urban development in the Netherlands. At the moment, many Dutch municipalities experience problems of oversupply of plans for development sites caused by the increase of competition between municipalities and of the degree of inter-urban fragmentation as a result of the crisis in the financial and land market.

Since the combination of geodesign and game theory is still rare, in this article we aim to test the applicability of facilitating these two fields in an integrated workshop. In order to do so, we will first describe the theoretical background in the next section. Afterwards, the institutional setting and context of the project are described, followed by further elaboration of the analytical framework, the game theory model and the setup of the integrated geodesign-game-experiment workshops. Subsequently, the experiences with the workshops will be presented and discussed in more detail. Finally, we will provide our conclusions and some recommendations.

2. GEODESIGN AND GAME THEORY AS CORNERSTONES FOR INTEGRATED STAKEHOLDER INTERACTION

For the integrated workshop, two strands of theory are combined: Geodesign (1) and Game theory (2) on negotiations among stakeholders. In literature, geodesign is sometimes combined with the methodologies of serious games (for instance D'Aquino, Le Page, Bousquet, & Bah, 2003; Vasconcelos et al., 2009), but literature on the combination of game theory and geodesign is very scarce. This article aims to bring these separated strands together and report on an attempt to bridge and combine the two approaches. Therefore, this theoretical section will provide a glance into both geodesign and game theory.

2.1 Geodesign

While Geographic Information Science has a quantitative, rational-analytic reputation and is therefore criticized under headings like qualitative GIS (Cope & Elwood, 2009; Schoepfer & Rogers, 2014) and critical cartography (see Crampton & Krygier, 2006), geodesign generally adopts a more qualitative approach to facilitating collaboration between stakeholders.

According to the founder of the well-known framework for geodesign, Carl Steinitz, geodesign is an interdisciplinary practice, emerging from the collaboration of professionals and stakeholders, working jointly on a shared focal spatial problem or place. Steinitz' framework organizes and supports these practices, integrating various approaches and methods. Amongst others, the practice of geodesign requires collaboration of design professionals, analysts (often with a background in geographical sciences), information technologies and 'people of the place' (Steinitz, 2012, p. 4-5).

In an effort to catch the practices under the label of geodesign, the following definition has been formulated: "Geodesign is a design and planning method which tightly couples the creation of design proposals with impact simulations informed by geographic contexts, systems thinking, and digital technology" (Michael Flaxman, 2010, in Steinitz, 2012). In the project described in this article, a simulation game is developed and played with stakeholders, in a way which shows similarities to the approaches and practices described as geodesign. In an iterative process, researchers and stakeholders work towards representations of real-world landscapes, and modifications in its physical structure. A (GIS-based) PSS serves to bring various themes and information sets together, and calculate consequences of certain decisions 'on the fly' during deliberations and negotiations.

2.2 Game theory for strategic decision behaviour

In short, game theory can be defined as a mathematical approach to study strategic behaviour (Myerson, 1991). In game theory a game is an abstraction of conflicting and interdependent decision-making situations. With its formal and abstract formulations, game theory can be useful to provide solid micro-foundations for the study of collective decision-making processes and also social interactions, especially related to the competition and co-operation among stakeholders (Elster, 1982). Furthermore, game theory has the potential to improve our understanding of collective action problems by describing the basic structure of collective actions, explaining how collective actions work and analysing potential outcomes of collective actions (Hardin, 1971; Aumann, 1985; Ostrom, 1990).

Game theory is not a single method of analysis. Rather, it has numerous features for exposing and analysing various interactional structures of stakeholders in various contexts and dimensions. The various dimensions can include the number of stakeholders involved, the way in which the stakeholders interact, and the availability of information to the stakeholders, and these dimensions can notably affect both structure and outcome of stakeholders' interaction activities (Dixit & Skeath, 2004).

Despite its many advantages, game theory also has many limitations. One of them is that some of its basic assumptions are excessively rigid, which may give difficulties in its application to complex real-life situations. Related to social dilemmas (e.g. public goods provision), many studies and experiments have been performed (see e.g. Fehr & Gächter, 2000; Bochet et al., 2006). However, most of those experiments occurred in laboratory settings involving undergraduate students at universities (Henrich, Heine, & Norenzayan, 2010). The specificity of such experimental settings raises questions about their generalizability and the effect that context may have on experimental outcomes, especially when local and spatial settings are crucial, such as in the case of supplying development land. Moreover, most local decision-makers, particularly at the municipal level, are not always taking urban systems into consideration when they make their decision: they often only limit their concern to their municipal boundaries. By applying a geodesign workshop in conducting a game experiment with municipality representatives ("the real people of the place"), we might expect that the effectiveness of the experiment will be improved. Not only to observe their strategic decision behaviour in a more realistic setting, but it will also provide them with a better decision support.

3. CASE STUDY: MUNICIPAL OVERSUPPLY OF DEVELOPMENT SITES

3.1 Institutional setting

In the Netherlands, the planning of urban development primarily is a municipal task and responsibility. Municipalities apply zoning plans that specify whether and how much development is possible within their boundaries. In addition, municipalities attempt to attract investors and private developers for funding the developments because more development results in higher income from taxes. As a consequence, there is a considerable degree of competition between municipalities for attracting investors in urban development. The provincial government is left with the task to supervise and coordinate the municipalities and intervene if necessary. However, provinces usually tend to give freedom to the municipalities to plan for urban development by themselves.

Since the financial and real estate crisis has hit in 2008, it has become more important for municipalities in a region, in deliberation with the province, to reach a common understanding of the total demand for housing and office space; supply of development plans nowadays exceeds the total regional demand. If prices of land will drop because this oversupply of development plans will be brought to the market, then a 'Tragedy of the Commons-situation' (as originally explained in Hardin, 1968) will become manifest.

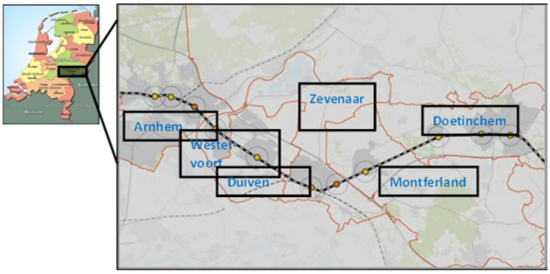

Figure 1. Municipalities in the Liemers transport corridor.

3.2 Case description

The case represented in the workshop is a real-world region with a problem of oversupply of development plans, anno 2014. In this article, we focus on the provision of locations for urban development in the case of the transport corridor between the Dutch cities of Arnhem and Doetinchem, the Liemers corridor (Figure 1), in the Eastern part of the Netherlands. In the Liemers transport corridor, connected by the A12 and A18 highways and the railway line Arnhem-Doetinchem, six municipalities compete by providing planned locations for future urban development. As a result of the competition and the limited demand for urban development at a regional scale, there is an oversupply of planned locations which considerably reduces the value of the locations (Table 1).

MUNICIPALITY	ARNHEM	WESTERVOORT	DUIVEN	ZEVENAAR	MONTFERLAND	DOETINCHEM	TOTAL REGIONAL SUPPLY	TOTAL REGIONAL DEMAND
Business area (ha)	12,0	3,0	33,5	20,2	27,0	113,0	208,7	120,1
Housing (no. units)	2000	536	682	1600	2057	2791	9666	8737

Table 1. Supply and demand of business area and housing in the Liemers Corridor until 2040. Based on EIB, 2013; IBIS-Province of Gelderland, 2013; Province of Gelderland, 2013.

The demand for future urban development can be regarded as a common pool resource. The six municipalities compete for this resource, and, in doing so, deplete the resource by providing for an oversupply of planned development. The solution to this problem can be found in a spontaneous collaboration (see Ostrom, 1990; Webster & Lai, 2003). An integrated geodesign workshop could provide for decision support to come to collaboration, by increasing insight in the problem at hand, simulation with potential solutions, and discussion of potential outcomes (e.g. Geertman, Stillwell, & Toppen, 2013). The set-up of such integrated workshops is described in greater detail in the next section.

4. METHODOLOGY: THE INTEGRATED GEODESIGN-GAME EXPERIMENT WORKSHOP

4.1 Analytical framework: Learning as a success criterion

As geodesign is understood as a team effort, group work criteria come into play for a successful project. In order for the workshop in terms of process and outcome to be successful, the geodesign team considered learning (individual and group learning) as the most important quality criterion for evaluating the project's success. This is in line with Vonk, Geertman & Schot (2005) and with Pelzer, Geertman, Van der Heijden, & E. Rouwette (2014) and Pelzer & Geertman, 2014), who made a systematic survey of added values of Planning Support Systems (PSS), eliciting communication and learning as proven, continuous elements, of successful group work with PSS for planning and decision-making. As learning should occur across disciplines, the four spheres of geodesign (Steinitz, 2012) should be incorporated in such a fashion that an iterative learning environment is created. We will now explain how we included these spheres as preconditions for enabling learning in the workshop.

The People of the Place sphere:

The workshop was not meant to simulate 'any region' or 'a fictitious problem', but concerns real stakeholders and a real-world planning problem, the oversupply of local development plans. In seeking an understanding of what stakeholders with real stakes do and think in weighing intervention dilemmas and in considering strategic cooperation and competition with other stakeholders in making their (individual and collective) trade-offs, their real-world situation should be represented in a recognizable fashion. A workshop setting requires sufficient simplification while remaining dedicated to the problem at hand. If the involved stakeholders would not consider it resembling their real-world situation, the developed approach would be considered a failure.

Geographic sciences sphere:

The research team acknowledged that a thorough inventory of plans and a trustworthy source of facts and figures would be necessary in order to make a valid, representative diagnosis of the problem. Data for preparing the workshops was collected with the involved stakeholders: the province, the metropolitan region and the six municipalities involved. We recognize the need for a thorough understanding of the spatial phenomenon being studied: the geography sciences sphere in Steinitz's spheres scheme. As in geography sciences, in this project the approach is premised on the idea to build a model based on the present, bearing sufficient accuracy, and then try to move it into the future.

Information technology sphere:

In early discussions about experimenting with decision-making in a workshop-setting with real participants, it was the intention that various expertises would be integrated. Planning support tools could be used to collect and represent (selective, 'what if') geographic information on local plans and area characteristics, while also incorporating or linking data on supply and demand of housing and business spaces (and related land prices and returns on investment). As the project unfolded, it became clear that the ideas for a negotiation game and the automated MapTable approach for visualizing dynamic simulations should be integrated. The negotiation game software would have the built-in pay-off structure of the underlying game-theory model, which calculates the financial consequences of various levels of (in-)equilibrium of supply and demand (section 4.2). The MapTable, running a dynamic GIS model (section 4.3), could serve as interface between the participants and the geographical information, as well as the game theory model in order to show financial consequences of decisions in real time. Based on previous experiences with collaborative planning and mapping processes and the MapTable instrument, there was a clear expectation on what could be represented in the short, compressed and simplified context typical for a game, how GIS visualizations could work in a workshop setting, and what would be (im-)possible in a collaborative setting with stakeholders (Mayer, Carton, De Jong, Leijten, & Dammers, 2004; Carton, 2007; Carton & Thissen, 2009; Arciniegas, 2012; Arciniegas & Janssen, 2012).

Design professions sphere:

It is in this sphere that the integrated workshop approach somewhat differs from that conceived by Steinitz (2012). For this particular project, dealing with an oversupply of plans, the financial-strategic negotiations between municipalities as to how to divide a burden of possible reduction of development plans, was considered the core issue. The exact outlook of the landscape or the exact choices where spatial development plans should be decreased or cancelled, was considered of minor importance, when dealing with the strategic interactions among the stakeholders. On the contrary, their mutual negotiations and trade-offs between options of burden sharing, accepting losses, competition and cooperation, were found central to the intervention part of the geodesign effort. The preparation and execution of the workshops aimed at finding creative inter-relational solutions for the stakeholders and increasing the understanding of the strategic considerations of stakeholders and the workings of supporting approaches and instruments (see also Samsura, 2014). By offering various potential planning interventions and intervention instruments to the workshop participants in consecutive game rounds, incrementally increasing the complexity, creativity would be triggered in a step-wise fashion.

4.2 Game theory model

The game-theoretical model employed in this study is based on a modification of N-person prisoners' dilemma game that was done by constructing continuous payoff structure and strategy space to the agents/players. The basic idea of the game is that subjects or players – who in this study represented different municipalities in the Liemers transport corridor – individually choose how many development sites they are going to supply. With a limited demand that is shared among all players, the aggregated supply will affect the expected values from developing the sites. It is somewhat indubitable to assume that when the aggregate supply exceeds the demand, the value will decrease and oppositely, the value will increase when the aggregate supply is below the demand. Players will then have to negotiate to adjust their plans for development sites. Changes made to the supplies will trigger real-time calculations of financial outcomes as values for each municipality involved, using the equation:

$$p_i = x_i \left(r - \left(\sum x_i - D\right)c\right)$$

$$\text{for } 0 \leq x_i \leq s_i$$

In this equation, p_i is the financial outcomes of municipality i, which can also be negative. The number of development locations, x, supplied by municipality i (in ha) is the only variable to be decided by the players. The other variables are given constants and consist of: r, the basic revenue based on specific cost and selling prices of every unit of development location in that particular municipality (in €); and D, the total demand for development locations in the corridor (in ha). When ∑x_i , the aggregated supply of development locations (in ha), is greater than D (i.e. there is oversupply), c is the reduction factor for the value of the municipalities development sites. Adversely, when ∑x_i is smaller than D (there is undersupply), c is the increasing factor for the value of each development site. Theoretically, the optimum level can be calculated by maximizing ∑p_i .The constants were gathered and calculated based on real data related to the cost and selling price of location development for each municipality and also on reports from the province and city-region authority that covers the study area (CBS, PBL and Wageningen UR, 2013; Cobouw, 2013; EIB, 2013; IBIS-Province of Gelderland, 2013; Province of Gelderland, 2013; VU University Amsterdam, 2011). Therefore each municipality has different values of x, r and c, based on their plans and profiles of costs and benefits structure related to their location development. Moreover, each municipality also has a maximum supply of development sites, si , based on their current development plans.

4.3 MapTable PSS workshop

Two geodesign workshops were organized, in which negotiations between the six municipalities were facilitated using financial and geographical data on residential and industrial developments. The first workshop was held with the regional urban development practitioners working as civil servants in the provincial government or city-region authority related to the Liemers transport corridor. In this workshop, we asked the participants to play the role of a representative of a municipality in the corridor. The second workshop was held with the local urban development practitioners from each of the six municipalities in the corridor. Each workshop was held as a semi-controlled experiment. Both workshops were videotaped with the purpose of assessing the participants' statements, observing their physical behaviour, and analysing the relation between the two, because people do not always behave according to rational principles (Neale & Bazerman, 1985), and the negotiation process defines how and why people have their particular way of thinking and acting (Rubin and Brown, 1975).

The MapTable PSS

A PSS with a digital map of the corridor area was constructed, which featured an integration of two main elements: an interactive GIS, a digital touch table, called the MapTable, and the game theory model, described above. As such, the PSS is a combination of what Schoop (2004) describes as an automation-oriented system, that tries to find any economic optimum of a negotiation process, and a communication-oriented system, that supports communicative processes. The MapTable is a digital touch table of large format (46-inch) developed and commercialized by the Dutch firm Mapsup (http://www.mapsup.nl) designed to support group work around spatial information. The PSS was developed within the ESRI ArcGIS® environment using an

ArcGIS extension called CommunityViz (http://www.communityviz.com). The extension CommunityViz is used to support users performing map-based calculations (Walker & Daniel, 2011), showing the results of their decisions in real time (Figure 2). The interactive interface and tools for the experiment were developed in cooperation with Mapsup.

Figure 2. Players negotiating around the MapTable PSS.

In the PSS, the supply of development plans is visualized using building blocks that represent a fixed amount of developments units (Table 2). The amount that is represented was chosen to easily alter the supply by each municipality. The initially displayed spatial distribution of blocks was modelled to match the current supply of both business and housing by each municipality, both in size and geographical location (Figures 3 and 4).

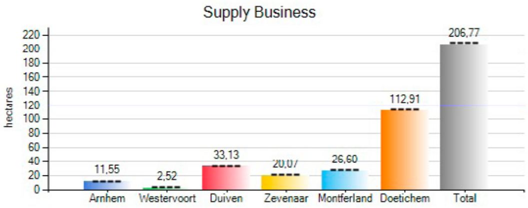

Figure 3. Initial distribution of supply of business areas. The blue line indicates demand for business areas in the corridor. Dashed lines on each bar indicate the single local supply for each municipality.

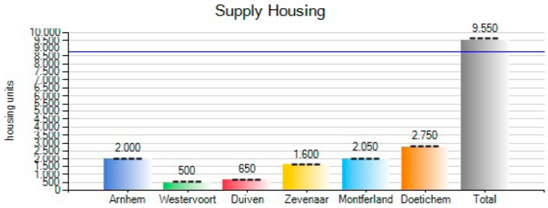

Figure 4. Initial distribution of supply of housing. The blue line on both charts indicates demand housing in the corridor. Dashed lines on each bar indicate the single local supply for each municipality.

TYPE OF BLOCKS	LARGE	SMALL
Business area (ha)	5,0	0,5
Housing (no. units)	200	50

Table 2: Representation of housing and business area by visualized types of blocks.

The PSS shows financial effects of a given spatial configuration of spatial developments (for both business and housing), by presenting a financial figure, in Euros, for each municipality separately and an aggregate value for the corridor (Figures 5 and 6).

Figure 5. Financial impacts for the initial supply distribution for projected business areas.

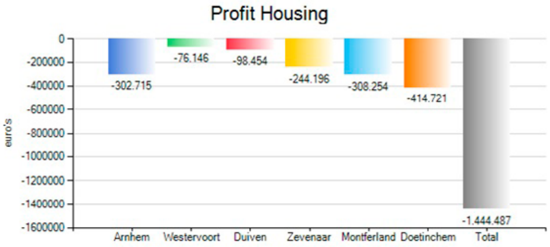

Figure 6. Financial impacts for the initial supply distribution for projected housing developments.

Workshop participants used the PSS to assess financial impacts of the initial spatial configuration of projected housing and business development, negotiate changes, and adjust their individual supply on the MapTable using their finger or a digital pen. They could either remove blocks, add blocks or by moving blocks from one municipality to another (by selecting one or more blocks within the municipal boundaries of one player and dragging this selection within the boundaries of a target municipality). If the participants changed the spatial configuration for spatial development, the financial figures were automatically reassessed in real time.

Workshop setup and game rounds

The workshops started with an introduction to the study area and the role of PSS. Next, a hands-on practice demo and instruction with the MapTable Planning Support System (abbreviated underneath simply as PSS) was given, which included:

- Map layers available in the PSS (municipal boundaries, spatial development plans, railway stations, roads, water bodies, aerial photography)
- Introduction to working with the library of blocks
- Charts showing supply of spatial plans
- Charts showing financial revenues for business and housing.

Subsequently, participants carried out four rounds of assignments in 2.5 hours involving negotiations about downsizing supply of plans (round 1), while taking into account public transport (round 2), new railway station development (round 3) and introduction of a financial compensation mechanism. The overall goal was to: “Modify the spatial configuration of supply of municipal development plans for 2025 using the profits displayed at both the individual municipal level and the corridor level”.

At three moments in the workshop participants filled in a short questionnaire regarding their expectations about the workshop, and experiences with the tool, as illustrated in the timeline of the workshop in Figure 7.

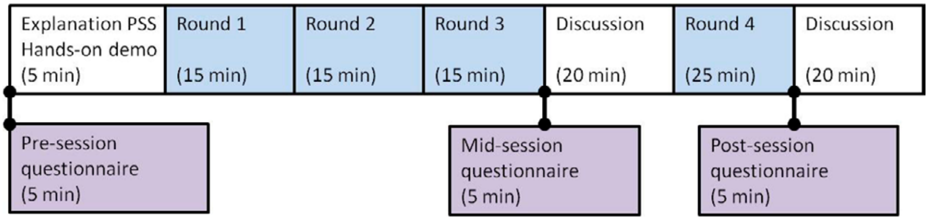

Figure 7. Timeline representing the experiment protocol of one workshop session.

5. RESULTS: EXPERIENCES FROM PARTICIPANTS

In this section, we describe the experiences from applying the workshops. We do this by highlighting the learning experience (section 5.3). However, first we describe the general observations on the performance of the visualisation and financial model (section 5.1) and the differences in process and outcomes between the workshops (section 5.2).

5.1 General observations

In general, the fact that the negotiation took place around an interactive map proved to be effective. It facilitated a focused form of communication, in which financial and spatial negotiations could be combined and supported by relevant information in order to come to an agreement. The tool helped to identify first steps towards obtaining a better regional adjustment of supply and demand in municipal locations for development and overcoming the common pool resource problem.

Figure 8. Stakeholders pointing to the map during their negotiations. Municipality territories are represented by different semi-transparent colours on the map, and the various graphs visualize the distribution of supply and demand for housing and office space.

All participants pointed to relevant features on the map in trying to explain their motives and justify their behaviour (Figure 8). In doing so, they used in-depth knowledge of their respective municipalities and brought forward spatial arguments to justify their behaviour. For example, in one of the workshops, the municipality of Zevenaar brings forward the importance of the international industrial area along the A12 highway, by zooming in on the location, turning on the underlying high-resolution aerial photography, and explaining the relevant geographical relation to the highway and the German hinterland.

Nevertheless, some of the participants felt that the broader spatial discussion on urban development was missing in the workshops. They felt that discussion with the tool "become too much of a financial story, and the spatial planning aspects are insufficiently discussed". The participants felt the urge to discuss more spatial aspects, look at more background maps, and illustrate that with issues, chances and opportunities in their own municipality. The set-up of the workshop did, however, force them to focus solely on issues related to oversupply. This was felt by the participants as too restrictive. For some participants, the financial information seemed to fuel the discussion more than the geographical information. Such remarks indicate that the integration of spatial information (central in geodesign) and financial information (put central in this game, using an N-prisoners dilemma conceptualization) needs to be balanced.

The relation between the financial model and the spatial information must be clear and transparent, according to the participants. They need to be aware of the preconditions and assumptions, which information is displayed, and which factors are included and excluded in the model, to be able to design the outlines of an agreement. As a participant notes in the questionnaire, in order for the negotiation to work, "insight in the figures is essential for a realistic negotiation". However, it is especially important for them to realize that the financial model simplifies financial relations in the real estate market, and that, as such, the exact outcomes are not of great added value. After all, the goal of the workshop was not primarily to simulate possible outcomes on the basis of a model, but to facilitate a discussion on the issue of oversupply of locations. This was clear to the participants, and the workshop was successful at it, as illustrated by this quote: "the tool helps to structure the discussion, specify each other's interests and subsequently confront each other".

5.2 Process and outcomes

The process and outcomes differed greatly between the two workshops, although it has to be stated that participants acknowledged the added value of both workshops.

Workshop with regional participants

In the workshop with the regional and provincial government, the participants easily reached an agreement on the amount of development locations to be supplied. It was commonly agreed that a general decrease of locations would help the financial result of all players, and that the largest suppliers should cut back their plans the most. This can be qualified as realistic, because of the regional perspective of the players in this workshop in which local sensitivities did not play a role: all players more or less acted in the common, regional interest. This can also be seen during the workshops: the participants displayed active poses and tried to look for possibilities, both within and outside their respective, assigned municipalities.

The iterations in the workshop merely helped to indicate whether the common regional interest was being served. The participants decided together what the best strategy was to reach the objective of limiting oversupply. The participants iteratively explored the limits of the model, and through trial-and-error the objective of limiting the regional oversupply was reached and distributed fairly over the different municipalities.

The main outcome of the workshop can be formulated as increased insight in the size and nature of the problem of regional oversupply, and the cross-municipal character of it. For now, the regional and provincial authorities still feel that the municipalities should solve the problem. After all, “the municipalities have caused the problem, they are feeling the consequences of it, so they should also increase their effort in solving it”.

Workshop with local participants

For the participants in the workshops with the local municipalities, this proved to be different. They could not come to a limitation of the supply of development locations. At the end of the negotiation an oversupply of these locations still existed. The negotiations with the players from the local municipalities had a tougher character in which participants negotiated more from a local perspective, serving their own local interests. Each player pointed to other municipalities to find solutions for the problem of oversupply. They used the map to identify and discuss locations in the neighbouring municipalities that otherwise might be overlooked.

The iterations in the Maptable PSS were used more restrictively than in the workshop with regional participants. They applied a drip-feed method, in which only small decreases were made to the amount of locations provided. Instead, the participants used the Maptable more as a discussion tool for explicating each other’s position in the negotiation.

The main outcome of the process was a call for more provincial involvement in formulating overarching spatial policies on regional urban development: “the province will have to deliver more tailor-made approaches. They have the instruments to intervene, why not do so? The province should carefully assess each municipal plan". Although the workshop successfully brings information together in interactive fashion with plenty of (financial) feedback, which can be used by the participants to design solutions to the problem of oversupply, this seems not to be sufficient for finding a solution to the problem of oversupply in this case study.

5.3 Learning

Although the workshops yielded different results as to reaching agreements (see Section 5.2), the added value of the integrated PSS for the various tasks was apparent to all players involved. The combination of the interactive map and real-time finances stimulated a discussion of the information. Participants questioned each other on the proposed plans and, especially, on the motives behind these plans. This is illustrated by remarks made in the questionnaire: "The tool effectively brings motives to the surface", and in the plenary discussion: "It is insightful. It relates to the essence of collaboration, which is crucial. It is a good tool to do so". The information technology offered a direct insight in each other's current situation and future plans. Therefore both learning about the position of other stakeholders, as learning about the issue at hand (the problem of oversupply in the Liemers corridor) occurred (Table 3).

	MINIMUM	MAXIMUM	MEAN	STD. DEVIATION	CRONBACH'S A
Learning about other participants	1,67	6,67	5,17	1,21	0,74
Learning about the issue	2,67	6,33	5,26	5,26	0,92

Table 3. Results of the objective to learn about others and the object at hand (N = 14; On a 7-point Likert scale with 1 = strongly disagree; and 7 = strongly agree)

The participants stressed that the tool effectively linked financial and spatial negotiations, which are usually taking place in separated arenas. The players used both the map and the financial data provided in the negotiation process. Especially the information from other municipalities, often belonging to other regions, proved to be useful. As one participant explains: "The extra information of the spatial element of the corridor versus the region is underdeveloped in negotiations in practice. That is information from another area and therefore usually invisible. As a municipality, you spend too little time looking around you to find out where the organizations and developments are that are essential for the success of your own plans".

The differences between the negotiation results of the workshops could point to the conclusion that the participants display real behaviour. The realistic character of the integrated workshop seems to trigger the behaviour that can also be observed in practice: at a regional level, one can find a solution for oversupply, but at the local level this seems much harder. The realistic character of the workshop was also stressed in the plenary discussion: “The workshop was very insightful. It is close to reality. It is not a fictive case, with the map and the locations. I think that helps a lot: you have to make it real”.

6. CONCLUSIONS AND RECOMMENDATIONS

In this article, we tested the applicability of facilitating both geodesign and game theory in an integrated workshop. We explored this for the Dutch case of oversupply of planned sites for urban development in the Liemers corridor. We specifically examined the way in which the integrated workshop can stimulate learning.

We can conclude that the combination of game theory and geodesign provides added value for planning support: it creates a realistic discussion and negotiation strongly connected to real-life locations, aimed at designing a common, regional solution. Participants learn about the problem and about each other through the provided interactive geographical and financial information.

The interactive tool especially proved to work well for generating insight in and learning about the issue at hand and each other’s motivation. The integration of geodesign and game theory therefore helps to add the contextual discussion of geodesign to game theory, while simultaneously it adds the financial strategic behaviour of game theory to the geodesign. The results, in the form of the distribution of locations and financial outcomes, merely served for making the negotiation more realistic, stronger spatially grounded and better supported by facts. The greatest added value lies in the insight generated in the process behind the outcome: e.g. how do municipalities interact, react to each other, and respond to changing circumstances? This seems to be in line with Lee (1994) and Te Brömmelstroet (2012), who argue that some problems are better approached through broad generalizations than through detailed models. This should be taken into account when considering the greatest disadvantages of the integrated workshops: the models applied offer a considerable (financial) simplification of reality. Therefore, the outcomes of the negotiations can only be used at a very general level.

In addition, the transferability of the integrated workshop is currently limited because the game-theoretical model is only applicable to settings in which an N-person prisoners' dilemma occurs. In its current form, it can only be used to analyse strategic behaviour in such settings. However, the integrated workshop may serve as an initial evidence of the possibility to integrate game-theoretical modelling and experiment with geodesign. By changing the structural variations in the game-theoretical model, we can analyse different situations. Moreover, we can also increase the complexity of a game in order to make it closer to reality. We strongly believe that the integration of game-theoretical modelling with geodesign may offer a promising approach for analysing complex urban development processes, because it particularly can take into account a specific interdependent situation among stakeholders in the process and the results of the analysis can be validated empirically through experiments with real stakeholders as we have done in this research.

Based on our work, several avenues for further research can be distinguished. The first is a further exploration of the potential of this tool. The tool proved to be useful in the first stages of a negotiation process, when information needs to be communicated efficiently. The application of the PSS in a later stage would require more in-depth information, and more sophisticated financial and spatial modelling. A second avenue is to broaden the sector in which the tool is applied. A cross-sectoral comparison could help to identify crucial preconditions in negotiations: e.g. what is the challenge central in a specific context and situation, which information is necessary for decision-making, how many players can be included in the strategic process, how could the strategic social interactions be included in the geodesign-negotiation-game workshop, and how can the problem best be visualized in the PSS.

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Detecting spatial features from data-maps

the visual intersection of data as support to decision-making

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Abstract

The assessment of spatial systems can be supported by the analysis of data coming from different sources and describing different aspects such as economic, social, environmental, energy, housing or mobility issues. Nevertheless, the analysis of such a large amount of data is difficult. In order to improve the readability of data also with non-technicians, new methods of communication are needed, which could facilitate the sharing of information among people with different skills and backgrounds. In this context, the paper shows the developments in geo-visualisation to support and improve the processes of planning and decision-making. First, the use of a map-based visualisation is suitable for intuitively understanding the location and distribution of specific elements. Second, the graphic interface can be used to drive users in the investigation of data. It can provide a linear method that is more comprehensive to the human mind in dealing with the complexity of spatial systems. In addition, the possibility to select and filter data by single attributes allows databases to be explored interactively and read by differently skilled users. The intersection and overlapping of information enables users to discover the relationships between data, the inefficiencies and critical areas, thus providing suggestions for further reasoning in planning and decision-making. Furthermore, collaborative and participatory sessions require quick answers and simple readability. Thus, the real time response to simple queries widens the opportunities for improving the discussion. A case study describes the methodology used for sharing the data collected during an Interreg IVB NWE Project named "CoDe24" (INTERREG IVB NWE, 2005; ERDF European Territorial Cooperation 2007-2013, 2010). By the use of a web-GIS visualisation tool, namely GISualisation, the project partnership was allowed to explore the data concerning the railways and train typologies along the Genoa-Rotterdam corridor. Despite the high factor of usability of the tool, it was not employed much by participants to the project so that further reasoning is needed to evaluate how digital tools are perceived by professionals.

KEYWORDS

GISualisation; InViTo; geovisualisation; Data analysis; CODE24

1. INTRODUCTION

A massive change in the availability of data is occurring. Until a few years ago, data were provided by authorized institutions or agencies in charge of monitoring specific elements. Nowadays, official data are just a small part of available data. Sensors distributed across the urban space gather information on traffic and pollution while satellites monitor the Earth. However, huge numbers of records are constantly produced by conscious and non-conscious users who act in their own daily life (Grauwin, Sobolevsky, Moritz, Gódor, & Ratti, 2015; Chicago Architecture Foundation (CAF), 2014; Kokalitcheva, 2014; IBM, 2014).

While most of these data are private, a large part is open and can be accessed by the use of free Web APIs. This can offer great opportunities for obtaining information about cities and other built environments, providing interesting descriptions of economic, social behaviour, environmental, energy, housing, transport or mobility issues. Furthermore, a large part of these data is geo-referenced, so that it can be easily gathered and localised on a map. The analysis of such data can provide focused studies on a specific area, generating information on localised dynamics and activities and by improving the assessment of a spatial system and its quality of life (Szell, Grauwin, & Ratti, 2014; Resch, Summa, Sagl, Zeile, & Exner, 2014; Chua, Marcheggiani, Serrvillo, & Vande Moere, 2014; Goodspeed, 2011; 2012; Neuhaus, 2011; Bawa-Cavia, 2010). Very detailed statistics can be captured by monitoring real activities, offering outcomes which can often be competitive with the output of traditional complex models.

In this context of a huge amount of information, spatial planning demands innovative methods. The paper shows the developments in geo-visualisation as a support to improve the processes of planning and decision-making. Opportunities and needs are discussed, presenting possible methods for new developments. A case study describes the methodology used for the sharing of data collected during the evaluation of the network along the trans-European railway axis (TEN-T) 24 Genoa-Rotterdam (Arnone et al., 2016). The study is part of an Interreg IVB NWE Project named “CoDe24” (INTERREG IVB NWE, 2005; ERDF European Territorial Cooperation 2007-2013, 2010).

2. A NEW TOOL: THEORETICAL OPPORTUNITIES AND PRACTICAL REQUIREMENTS

As in all scientific and professional disciplines, also spatial planning can now exploit the opportunities given by ICT for the development of innovative tools and methods. The current state of the art is still a combination of traditional methods, which only occasionally make use of the new digital technologies. The last decades have strongly built up the trust in technology among professionals, so that also new communication and information sharing systems are often perceived too complex to be used in real planning processes.

2.1 The rise and fall of complex spatial models

During the last half century, spatial planning has evolved into a multi-disciplinary science, which considers and analyses the spatial system as a multitude of heterogeneous elements linked to each other through intricate connections. The mono-functionalism of modern spatial planning, as well as the independent approach of professionals acting within the cities (Jacobs, 1961; Alexander, 1965), were no longer suitable for the growth of contemporary cities. Linear planning theories were substituted by the rising idea of the city as a complex living system.

New theories on complexity have generated a large number of visions of the world (Allen, & Sanglier, 1981; Batty, 2003, 2005; Portugali, 2011; Portugali, Meyer, Stolk, & Tan, 2012; Salingaros, 2000, 2006). As a natural consequence, spatial planning grew into a multidisciplinary science, where a large number of professionals contributes with specific expertise and insights into specific fields such as social sciences, environment or transport. In addition, spatial planning also has to consider a wide range of other non-scientific elements such as the interests and goals of both private and public stakeholders who commonly act in spatial systems. Therefore, the spatial configuration is the result of the unravelling of intricate knots which tie functions, activities and forms to a specific space.

While the reasoning around complexity was growing, the methods and tools for urban planning have been reviewed. In particular, large-scale models have generated a diffused interest within the scientific world. Since the Sixties, several studies have been produced with which to regulate and measure the planning of cities. Many theories have been developed but their outcomes failed to convince professionals. They reached a final peak in 1973, when Lee listed their more evident flaws as an obstacle to their usability. Nevertheless, during the Eighties the progress in computer science and, in particular, the development of graphic interfaces brought a new technological opportunity to continue the reasoning on large-scale models. During the Nineties and the first years of the second millennium, a vast production of literature arose on the theme of digital spatial models (Harris & Batty, 1993; Klosterman, 1994, 1999; Landis, Monzon, Reilly, & Cogan, 1998; Waddell, 2000; Waddell et al., 2003; Wegener, 1994, 1995; White, & Engelen, 1997, 2000; Wolfram, 1984). The introduction of powerful technological tools enables the idea of a new digital era able to face the challenges of large-scale models (Klosterman, 1994; Landis, 2001). Studies on the complexity of cities provided a strong theoretical background and support to the development of spatial models. In particular, they justified a general pursuit of translating the full set of qualitative spatial dynamics into an automatic quantitative process.

Cities, as well as their activities, dynamics and behaviours, have been analysed through a wide number of data, variables, parameters and indexes, using several methodologies which increased the common need for detailed, precise and complete data. The search for good quality data became an incessant challenge for implementing, calibrating and validating models. Therefore, the studies on large scale models developed into very complex instruments, whose structure was conceived to include different elements such as land-use and transport (also known as LUTI models), social, environmental or economic factors, considered statically and in their possible evolutions in time. As a result, this approach resulted in tech-oriented research, which forgot the ultimate goal of improving the spatial planning processes. Large scale models increased their performances but remained "hyper-comprehensive, gross, data hungry, wrongheaded, complicated, mechanical and expensive" (Lee, 1973), while their transparency, assessment abilities, suitability to particular needs, and simplicity were not improved as expected. Persistent attempt of reproducing the real world in order to automatically generate forecasts and solutions for a living system, deeply undermined their inner usefulness. According to Borges (1960), a 1:1 scale map of the empire is useless. Models should be an abstract selection of reality (Farinelli, 2007), which may be of practical use for obtaining information, knowledge and awareness about specific issues.

Nevertheless, many tools are still overly complex. Non-technicians are generally limited in the process of data exploration, while too often technical expertise is required for both the production and understanding of maps. The need for tools based on linear logic is now recognised. Today criticism of spatial models and their counterparts referred to as Planning Support Systems (PSS) or spatial Design Support systems (sDSS), confirms the point of view of Lee (1973) and points out the common need for simplicity, user-friendliness and transparency in order to be usable by a large variety of users (Uran, & Janssen, 2003; Couclelis, 2005; Vonk, Geertman, & Schot, 2005; Vonk, 2006; Geertman & Stillwell, 2003, 2009; Te Brömmelstroet, 2010). Some discussions have arisen in the last years in order to highlight the differences between complex and simple models (Klosterman, 2012; Hoch, Zellner, Milz, Radinsky, & Lyons, 2015). However, Information and Communication Technologies (ICT) significantly changed the perspectives and possible uses of automatic processes within decision-making processes. From the misconception of spatial models as a crystal ball, able to provide forecasting and spatial solutions, the study of living systems is moving towards the use of simpler frameworks and more user-friendly interfaces.

2.2 Data analysis as new approach to spatial planning tools

With Big data on one side and the need for more linear methodologies on the other side, spatial planning is being pushed towards a data-driven approach (Kamenetz, 2013; Lanzerotti, Bradach, Sud, & Barmeier, 2013). Subsequently, systems of spatial and/or visual analysis are being investigated to find new methods which could increase the readability of information contained in data (Grauwin, Sobolevsky, Moritz, Gódor, & Ratti, 2015).

Historically, human minds use analysis as a learning method, demonstrating how cognitive processes are facilitated by the use of a simple and linear approach. In fact, according to the etymological definition, analysis is the deconstruction of a whole in its simplest elements. The consequence is a linear process which implies the investigation of three main issues:

- The identification of each single part;
- The definition of the relationships and hierarchy between the parts;
- The definition of the relationships between the parts and the whole.

Analysis can provide information regarding location and the order of things on Earth (Schmitt, 1950), providing all the elements necessary for knowing a spatial system through a hierarchical and logic sequence. The analysis of flows of data can provide alternative applications to complex spatial models, offering a linear approach to spatial studies. In particular, geo-data analysis is currently characterised by the use of interactive and visual tools, namely geo-visualisation tools (Andrienko, & Dykes, 2011). Based on dynamic maps, geo-visualisation aims at sharing geographic information in order to improve the knowledge of spatial issues among different kind of users. Therefore, the exploration of data becomes a way for analysing huge amounts of data through a simplified visual interface. This has been shown to be particularly suitable for improving the comprehension of spatial issues by both people with no particular expertise or technical skill.

2.3 Requirements for data readability and usability

Data including geographic information are known as GIS data. They are collected in spreadsheets where each line corresponds to a geo-referenced geometry, and each column, namely field, contains an attribute of the geometries. Although these files can include a high level of information, their representation is generally provided by maps which show few fields of attributes. Thus, the resulting maps generally omit many elements which could be useful to their interpretation. These kinds of maps, also known as data-maps, show the spatial distribution of values, but do not reveal the hidden connections among data. Therefore, the message given by data-maps is often too simple and does not provide a relevant insight into the spatial features.

Today, geo-visualisation technologies, such as web-GIS tools, provide many opportunities for the development and customisation of mapping instruments. Common users can choose a large variety of tools from both commercial and open products, through a large variety of tools. Applications of such instruments are available worldwide and concern a number of fields. Nevertheless, only a limited number of existing tools are usable in real-life planning contexts. Generally, the reason is due to a misconception of tools. Frequently, the use of visualisation is oriented to eye-catch the users, rather than to improve their learning process on specific fields. Thus, the exploration of spatial data is often limited to a barren overlay of different maps. Furthermore, planners and decision-makers have to share their expertise, interests and opinions with people with different levels of expertise and skills. Thus, the readability of data should deal with the skills of people involved in the process of planning and decision-making. Data readability demands new instruments to help prevent misunderstandings, facilitate the sharing of information and enhance the communication value of analytic processes. Policy-makers, professionals and stakeholders should be informed about all project issues before the conclusion of the decision-making process. In particular, they need to be aware of all the possible consequences to their choices. The opportunities given by ICT can aid their activities, especially by simplifying the processes of information sharing and by enabling the exploration of data.

Furthermore, interaction can improve not only data readability, but also the usability of tools (Andrienko & Dykes, 2011; Andrienko, et al., 2007, 2011). Usability is now a keyword in the conceiving of support systems. Both expert and non-expert users are increasing their interest in data exploration systems working in real time. Even if the attractiveness of new technologies can play an important role in the diffusion of this trend, two main reasons can be noted in the opportunities provided by interactive systems.

First, only a few tools are conceived to cut across various disciplines and uses, so that their usability is confined to a very limited number of applications. Second, the interaction with data improves the direct dialogue between users and data. Instead of trusting on time-intensive calculations made by black box systems (Latour, 1987), users prefer to personally investigate the information contained within data. Thus, the learning process is facilitated by the personal construction of possible connections and hierarchies between the parts. Furthermore, the dialogue with data increases the respect for the human experience in front of calculations given by automatic processes.

Often, experts do not trust the outcomes of complex calculations because of the low transparency of processes. Avoiding black boxes reduces suspicions concerning digital tools. A number of workshops supported by the use of map-based tools have shown that experts often look for problem explanations instead of problem solutions (Abastante, et al., 2014; Masala, Pensa, & Tabasso, 2014). The absence of complex mathematical formulas and the direct comparison between the attributes of data can be a simple way to represent the information included in data. By using interactive and user-friendly interfaces, users can find their solution through a process of self-learning, which exploits the value of personal experiences enhancing the strengths of individual skills.

2.4 The development of a new tool

The research presented in this paper was looking for the integration between GIS technologies, spatial decision-making and communication. A new tool, namely GISualisation, was developed in order to satisfy specific requirements of usability in decision-making processes. Based on open web-platforms and applications, the tool is a geographical data viewer aimed at facilitating the reading, understanding and sharing of data. Its main goal is not to provide definitive solutions, but to help users identify elements corresponding to specific parameters and the relations between elements. New ways for using spatial data have been investigated in order to improve the process of communication and knowledge of cities and territories. In order to explore data, the tool works on dynamic maps, created by the use of free map-based web applications. Maps containing geo-referenced data can be easily explored, as with traditional WebGIS tools, but data can be filtered along different levels of details. On a lower level, information can be grouped in macro-categories such as layers or fields, while on a higher level, databases can be investigated on the basis of single records. Thus, geo-data can be analysed record by record, filtering data and locating their attributes. In order to overcome the low information value of data-maps, one possible solution was found in the intersection of attributes from different fields. By applying filters to the contents of one or more fields, map-users can obtain information about each single attribute and relate it to other elements such as its location on a map or the values of other geometries. The exploration of these relationships between data can allow people to deepen their knowledge on displayed data. Furthermore, the possibility of interacting easily with large databases could provide a support for planners and decision-makers to detect factors of inefficiency, ineffectiveness or critical areas which need further reasoning concerning their planning or design.

Information can be freely interpreted by the actors involved within planning processes, who can use their personal experience to analyse data and look for common and shared solutions. In this sense, the development of GISualisation has favoured human skills over technological power and automatic processes, attributing a new value to the presence and participation of people.

New methods of communication were investigated to improve opportunities for the sharing of information and learning. Benefits for improving the knowledge process can come from the use of the graphic interface as a fil rouge for guiding the user in the exploration of data. The interface was conceived as simple as possible. A vertical menu on the left side of the screen hosts all the instruments for data filtering, such as sliding cursors, scroll-down menus or checkboxes. The remaining area of the screen displays a dynamic map. These two elements form a necessary and sufficient condition for supporting the spatial decision-making processes. In fact, data can be grouped by users on the basis of families or ranges and visualised on the map. This combination between a phenomenon and its localisation produces a strong conceptual relationship, which is essential in understanding spatial dynamics (Dodge, 2005). Through an easy-to-use interface, both experts and non-experts can follow the sequence of filters, explore the interrelations between data, and collect visual information on cities and territories. Thus, data visualisation increases the intuitiveness in data reading, improving comprehension and increasing benefits for decision-making processes.

3. CASE STUDY: THE DEVELOPMENT OF THE GENOA-ROTTERDAM CORRIDOR

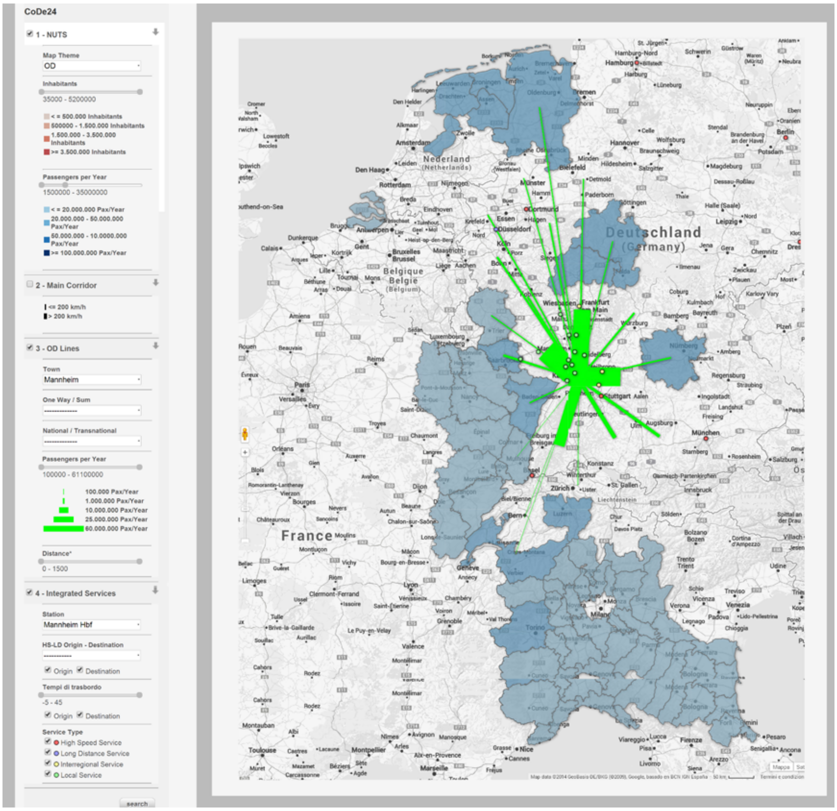
The flexibility of GISualisation has been proved through a number of applications, ranging from the investigation of inefficiencies in the public transport system of the Piedmont region in Italy (Pensa, Masala, Arnone, & Rosa, 2014; Isabello, Pensa, Arnone, & Rosa, 2014), to the analysis of health of urban population, from the study of pedestrian paths in urban areas, to the evaluation of social housing projects. In particular, this paper describes a further project concerning the study of the trans-European railway axis (TEN-T) 24 Genoa-Rotterdam (Arnone et al., 2016). The CoDe24 project focused on the European railway network connecting the ports of Genoa, Italy, and Rotterdam. The international scope of the project required a geographical diverse partnership. Project members represented all the nations crossed by the corridor: Netherlands, Germany, France, Switzerland and Italy. The same diversity was required from disciplinary backgrounds and skills. Since the main purpose of the Code24 project was the interconnection of spatial, transport, economic and ecological development along the railway services, the disciplinary fields of members were varied. As a consequence, the communication between the partners was complicated by the presence of several typologies of languages. Thus, a common platform was needed for information sharing. A first GIS platform hosted by the ETH of Zurich was used, after which all data concerning the Code24 project were moved into a GISualisation project.

3.1 Data collection and representation

Data about the Corridor 24 Genoa-Rotterdam project were gathered from different sources and collected in a number of databases. In order to share the information among the partners of the project and public users with different skills and backgrounds, databases were structured to be displayed in the simplest of interfaces. Four main typologies of data were identified:

- Quantity grouped by Nomenclature of Territorial Units for Statistics (NUTS);
- Typology of railway tracks along the corridor;
- Origin-Destination (OD) lines;
- Integrated services.

Each of these typologies of data was uploaded in GISualisation, through which it can be explored at different levels of detail (Figure 1).



CoDe24

☑ 1 - NUTS

Map Theme
OD

Inhabitants
35000 - 5200000

Passengers per Year
1500000 - 35000000

☐ 2 - Main Corridor

☑ 3 - OD Lines

Town
Mannheim

One Way / Sum

National / Transnational

Passengers per Year
100000 - 61100000

Distance*
0 - 1500

☑ 4 - Integrated Services

Station
Mannheim Hbf

HS-LD Origin - Destination

☑ Origin ☑ Destination

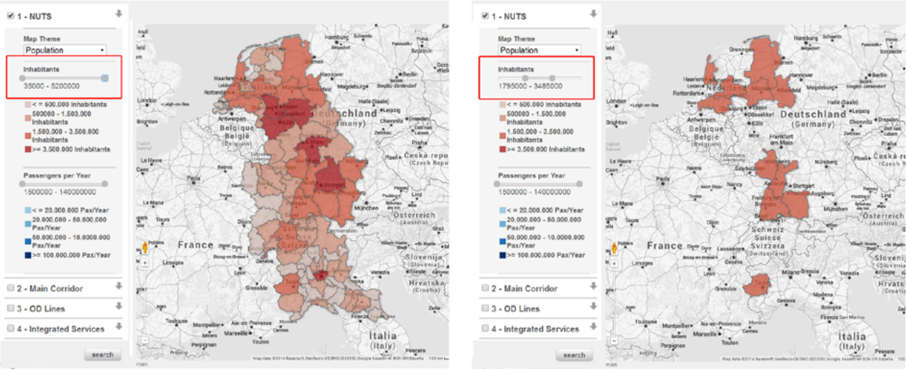
Tempi di trasbordo
-5 - 45

☑ Origin ☑ Destination

Service Type
☑ High Speed Service
☑ Long Distance Service
☑ Interregional Service
☑ Local Service

Figure 1. Screenshot of CoDe24 project within GISualisation, representing an example of data visualisation and map overlapping.

The first typology is conceived to show the territorial context in terms of the number of inhabitants and the number of passengers per year. Data are grouped into territorial units for statistics (NUTS) and are visualised by means of a colour gradient scale. Through a slider cursor, users can select are as corresponding to a specific range of values, so as to customise the views and to provide the possibility to visually inter-relate this data with other information (Figure 2).



Map Theme: Population

Inhabitants: 35000 - 5200000

Passengers per Year: 1500000 - 140000000

Map Theme: Population

Inhabitants: 1795000 - 3485000

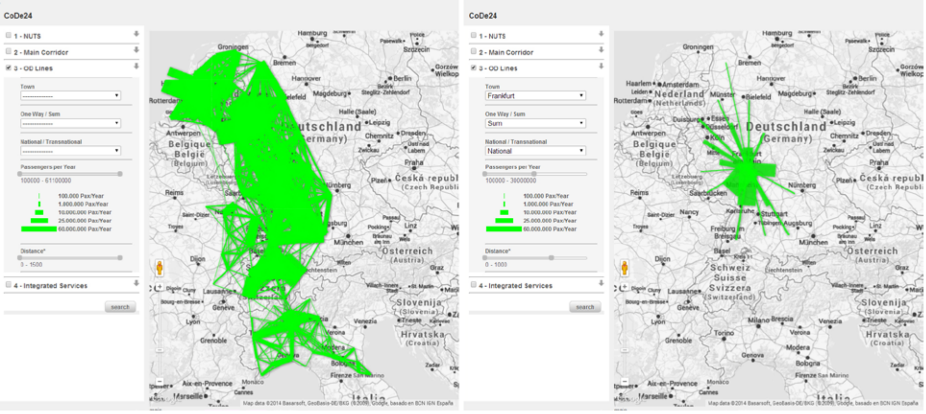
Passengers per Year: 1500000 - 140000000

Figure 2:

Figure 2. The comprehensive data concerning the number of inhabitants along Corridor 24 (on the left) and the selection of regions within a specific range of population (on the right).

The second typology of data cannot be filtered but it is useful in understanding the route of trains along the corridor on the basis of their speed, that is, lower or higher than 200 km/h.

The third typology concerns the Origin–Destination (OD) Lines, and has been provided by ETIS+ project (ETIS plus, 2010). In this section, users can decide to display data by applying a number of filters, such as origin town, typology of direct services as one direction or sum of both directions, national or transnational services, number of passengers per year and distance in km (Figure 3).



Town: --------------

One Way / Sum: --------------

National / Transnational: --------------

Passengers per Year: 100000 - 61100000

Distance*: 0 - 1500

Town: Frankfurt

One Way / Sum: Sum

National / Transnational: National

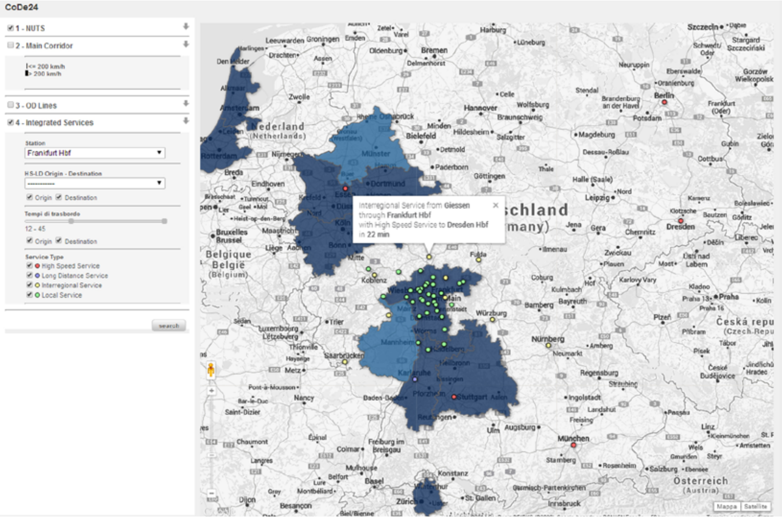
Passengers per Year: 100000 - 38000000

Distance*: 0 - 1000

Figure 3. On the left, the figure shows all the OD lines along the corridor. On the right, data have been filtered in order to show the situation in the city of Frankfurt, by considering selected ranges of data.

The fourth and last typology is designed to investigate the integration among the different railway services (e.g. High Speed (HS) and Long Distance

(LD), or InterRegional (IR) and Local (L) trains) through several stations along the corridor. This section takes in consideration data concerning trains arriving in each station from 8.00 to 9.00 a.m. and provides information for all possible destinations that can be reached combining HS/LD with IR/L services within a specific transfer time frame (Figure 4).



☑ 1 - NUTS
☐ 2 - Main Corridor
<= 200 km/h
> 200 km/h
☐ 3 - OD Lines
☑ 4 - Integrated Services

Station: Frankfurt Hbf
HS-LD Origin - Destination: ------------
☑ Origin ☑ Destination
Tempi di trasbordo: 12 - 45
☑ Origin ☑ Destination

Service Type
☑ ● High Speed Service
☑ ● Long Distance Service
☑ ○ Interregional Service
☑ ○ Local Service

Interregional Service from Giessen through Frankfurt Hbf with High Speed Service to Dresden Hbf in 22 min

Figure 4. Selection of integrated services at the station of Frankfurt Hbf, with a transfer time ranging from 12 to 45 minutes, overlapped with NUTS areas with more than 85.000.000 Passengers per Year.

3.2 Visual analysis and collected information

The visualisation provided by the use of such WebGIS tool increases the opportunity for discovering the hidden information included in the records of a dataset. Charts, tables, filters and maps enable the visual analysis of data. At the same time, users have the possibility to overlap different maps and see the combination between several typologies of data (Figure 5).

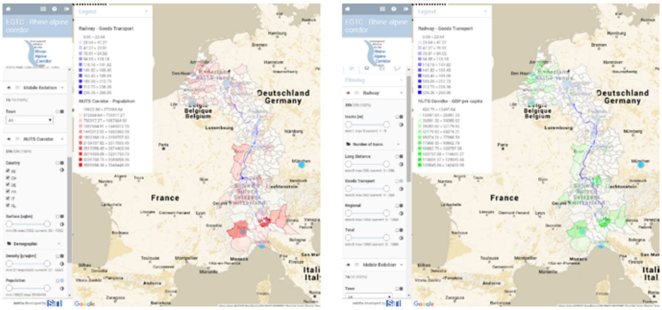


Figure 5. Overlapping of different maps to see the combination between several typologies of data and to investigate the spatial distribution of services.

In particular, data can always be related to their spatial location, thus allowing users to understand the connections between data and their spatial influence. For example, users can easily understand the distribution of railway services along the corridor Genoa-Rotterdam. First, the different sets of data, and their sequence in the menu on the left side of the graphic interface, work as a guideline in the exploration of data, facilitating users in choosing the element to be investigated. Second, the use of maps makes it easy and intuitive to understand the localisation and distribution of areas with the highest and lowest levels of railway facilities. The map can show the density of connections between the Northern and Southern parts of the corridor, but they can also show if these connections are used. In fact, some slider cursors allow the user to customise the data visualised and to determine the values of parameters such as the number of passengers per year, the lines supporting high-speed trains or the integration between different trains in the stations of major cities along the corridor.

In this case study, the visual analysis of data has been applied to study the railway infrastructure and facilities along the corridor. Although it does not provide calculations, nor quantitative values, its outcomes can be used for the construction of a rationale, which can be shared on a common platform with all the actors involved in the process. Such a visualisation can be used later as the basis for the discussion of possible strategies or planning solutions. Therefore, the use of a dynamic visualisation tool proved effective in highlighting some issues in the European railway system that can be discussed with the partnership of the CoDe24 project.

4. CONCLUSIONS AND OUTLOOK

Through the visual analysis of spatial data, GISualisation offers a new approach to actors involved in the planning process, tasked with detecting critical areas and improving the urban planning process. Spatial data can be investigated and visually analysed so that users can perceive the direct relationship between data by their own visual experience, thereby reaching a new awareness of the information visualised. The visualisation of data can be organised on the basis of specific requests in order to meet the goals of a planning issue as far as possible. Its interactive interface removes the waiting times during collaborative meetings such as workshops or decision-making sessions, thus offering a dynamic platform for building shared knowledge. In fact, the visualisation acts as a common element on which discussions can be based, so that it can aid real time exploration of “what if” scenarios requested by the different actors.

In some cases, GISualisation can offer a valid substitute of spatial models, especially when the overlapping of geo-referenced data can provide exhaustive responses to the planning issue on its own. The visual analysis of the values of a specific element, also in its temporal evolution, can provide users with a large amount of information, so to enable users to apply their personal experience and skills in understanding trends, critical and robust areas, as well as possible planning solutions. In this way, users are supported in exploring and intuitively understanding spatial data, while, at the same time they are involved with the whole suite of their professional experiences in the reasoning about the future of an area. In other words, the tool can show the single pieces of a complete puzzle, but the responsibility of re-composing the final form is left to the human knowledge of the planners.

GISualisation is a tool for the visualisation of data. This means that it can work as a common platform for the sharing of information between people, especially in collaborative and participatory sessions, where the need for a homogenous form of communication is essential to improve the awareness of participants.

The tool is now facing a new implementation concerning the graphic interface, the back-end interface and its user-friendliness, which should increase usability by non-expert users. Further developments concern the integration of GISualisation within the Interactive Visualisation Tool (InViTo) (Pensa, Masala, & Lami, 2013; Pensa & Masala, 2014). GISualisation is now the data-filtering component of InViTo. This combination with a multi-criteria analysis tool strengthens the capabilities of the web platform. Today, their combination empowers users to manage and explore data concerning cities and territories, while also providing a method for applying mathematical curves in the visualisation of sets of data. Depending on the type of case study, the tool can be adapted and customised to visualise different type of data, ensuring the possibility to explore the relationships between data.

To conclude, GISualisation does not have the capability of replacing a large-scale model, but aims at opening the gaze on data-oriented landscapes which concern the management of a huge number of data sets, and the common need for simplicity and user-friendliness. Its purpose is to alleviate the daily practice of many planners who deal with large amounts of data which are often incomplete or unsuitable as an input in complex models. Furthermore, it offers a human-centred tool, which, while not providing a solution, supports planners in improving their idea and sharing it with the other stakeholders. Thus, a new approach to geo-referenced data in planning can be useful in finding new and simple systems which stand to improve the planning practice and the role of the planner itself.

The usability of the tool has been proven during a number of workshops and meetings. Nevertheless, additional considerations could be developed on how professionals, decision-makers and stakeholders perceive the usability and utility of digital tools. If individual technical skills affect the ease of approaching such instruments, a general mistrust manifests itself when the use of a tool is not adequately presented. This experience showed that single users do not autonomously use spatial support tools. Their utility is recognised only when they have been introduced with sufficient explanation. Thus, although the interface was studied to guide the users in the exploration of data, the use of the tool requires human interaction in the form of a facilitator who can lead the professionals in exploiting its utilities. Despite the high usability, tools by themselves cannot substitute the process of discussion and/or debate, nor can they substitute the presence of a project leader who can direct the process of data analysis, exploration and knowledge.

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LAND USE, URBAN & FACILITY MANAGEMENT

Geodesign the multi-layered water safety

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Abstract

This paper aims to frame the multi-layered water safety concept in the context of a systematic, thorough, multidisciplinary and collaborative methodology for complex problems solving, i.e. geodesign. Multi-layered safety is an integrated flood risk management (FRM) concept based not only on flood probability reduction through prevention (layer 1), but also on consequences' minimization in the case of a flood through spatial solutions (layer 2) and crisis management (layer 3). It has been introduced in the Netherlands in 2009 following the European Flood Risk Directive adopted in 2007. In this study, the multi-layered safety is qualitatively assessed, demonstrating that it rather resembles a parallel system, and that collaboration is required to decide about the most desirable safety measures, which should not only be based on their economic efficiency but also on their social acceptability. In the light of these factors, we attempt to methodologically systematize the multi-layered safety concept by following the geodesign framework. The latter means that, through its implementation, understanding of the current situation of a particular area of interest, which in turn it may support, the allocation of weights regarding the three layers of the multi-tier safety concept is facilitated. Furthermore, the geodesign of the multi-layered safety shows that participation and interaction of the safety policy makers, as well as iterations for achieving maximum consensus between them concerning the more balanced safety measures, taking into account their economic efficiency, their impact on the environment, the local circumstances and the values of the people at place, are methodologically enabled.

KEYWORDS

Multi-layered water safety; Geodesign

1. INTRODUCTION

Flood risk management (FRM) in the Netherlands currently focuses on technical flood prevention measures such as levees and dikes (De Moel et al., 2014). However, in Europe flood management is moving towards an integrated risk management approach where measures about exposure and adverse consequences are considered (Büchele et al., 2006). This movement is motivated by the European Flood Directive (2007/60/EC) which urges EU member states to adopt a risk-based approach that takes into account potential consequences of floods next to their probability (Kellens et al., 2013). In the Netherlands, the multi-layered safety concept which consists of three layers, i.e. (1) prevention; (2) damage reduction via sustainable spatial solutions, and (3) preparation for emergency response, has been introduced as a reaction to the European Flood Directive in order to support a flood risk-based management approach (Ministry I & E, 2009). Nevertheless, the application of this concept is still in its infancy and a focus on preventive measures (layer 1) is obvious (De Moel et al., 2014).

The implementation of the multi-layered safety concept needs the combination of objectives and funding from various policy domains at different spatial scales and for several temporal horizons, the involvement of various disciplines and the collaboration between stakeholders with several interests and means (e.g. Potter et al., 2011). Required protection levels may vary between different areas, which may have different flood regimes. The optimal solution for Dutch flood safety can be a combination of measures from the three layers that jointly can minimize the overall flood risk (Ministry I & E, 2009). Without discussion and visualization of the impact of alternative water safety measures, their context cannot be understood so that they reflect local conditions and specificities. Furthermore, different stakeholders have different expectations regarding water safety. For instance, residents of a study area may aim to maintain a high level of flood security, irrespective of economic and environmental costs, technocrats may seek to preserve a significant level of water safety by keeping in mind the economic efficiency of the different measures, while public officials may see the same area as a vehicle to implement programs to achieve their political goals.

In the context of multi-layered water safety, a single methodological framework which determines the roles of different stakeholders, promotes dynamic visualization and communication of the current situation, enables the comprehension and evaluation of proposals and permits feedback in the necessary phases does not exist. In order to overcome the lack of methodology, the main goal of this study is to orchestrate the multi-layered safety concept in a geodesign framework-oriented decision-making process (Steinitz, 2012).

This study commences its mission by describing the main recommendations for flood safety and practices in Europe (section 2) followed by the Dutch perspective (section 3). In this context, the multi-layered safety concept is analyzed, attempting to demonstrate the need for a methodological framework which stimulates stakeholders' participation and active citizenship, experimentation and impact assessment, in order to reach optimal combination of safety measures tailored to the specific characteristics and conditions of an area of interest. The remainder of this paper is organized as follows: Section 4 provides definitions of geodesign and outlines geodesign framework and models. Section 5, firstly describes data underlying the multi-layered water safety concept and secondly it attempts to theoretically systematize this concept in a geodesign framework. Finally, section 6 presents the conclusions of this paper.

2. FLOOD SAFETY IN EUROPE

Floods are the most dominant natural hazards in Europe (Bakker et al., 2013). According to the European Environmental Agency (2010), only between 1998 and 2009, Europe suffered over 213 major damaging floods, which have caused some 1126 deaths, the displacement of about 500 000 people and at least € 52 billion in insured economic losses. However, by taking the right measures their likelihood can be reduced and their impacts can be limited. The need for developing comprehensive European water legislation was initially identified by the council in 1988, which has resulted in bilateral meetings of officials from France and the Netherlands to discuss the integration of European Water policy legislation (Bakker et al., 2013). Following an informal meeting in April 1995 between the Netherlands, France, Germany, the United Kingdom and Spain, a joint position paper was drafted which formed the basis for a wider consultation between water directors of all European Union (EU) member states. This process led to the adoption of Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy, known as the Water Framework Directive (WFD). Although WFD deals with integrated water management, water quality and ecology (EU, 2000), the flood protection is not explicitly faced in it. Thus, a European approach to flood protection was put on the agenda resulting firstly in a Flood Action Programme in 2004 and later in the adoption of the Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks known as the Floods Risk Directive (FRD) (Bakker et al., 2013). Introduced here are the FRD along with the Hyogo Framework for Action (HFA), which form two key recommendations for the protection of those at risk, and the main safety practices in Europe are explored.

2.1 The main recommendations for flood safety

Floods cannot be completely eradicated (Mostert & Junier, 2009) and for this, on the European level, attention has been moved from protection against floods to managing flood risks (e.g. Klijn et al., 2008; Twigger-Ross et al., 2009; Hecker et al., 2009; Vinet et al., 2008; Manojlovic et al., 2008). This fact is reflected in FRD, which entered into force on 26 November 2007. FRD is the first directive of the EU (Mostert & Junier, 2009) that deals with floods, requiring from the member states to perform a preliminary assessment of flood risks, mapping the flood extent, assets and humans at risk, prepare flood risk management plans for the regions under significant flood risk, and take adequate and coordinated measures to reduce this risk (EU, 2007). According to the directive, EU member states have to facilitate public participation, reinforcing public rights to access information and related measures about flood risks and to influence the planning process (ICPDR, 2012). In addition, EU member states have to coordinate the implementation of the FRD with the WFD. The driving force for this coordination is that physical flood protection infrastructures are some of the key drivers for determining the ecological status of waters with regards to hydro-morphological quality elements (Santato et al., 2013). In addition, a number of measures which focus on flood risk reduction can have multiple benefits for water quality, nature and biodiversity as well as regulate water flows and groundwater restoration in water scarce areas (Brättemark, 2010). In brief, preparation of river basin management plans under WFD and flood risk management plans under FRD are elements of integrated river basin management and thus their mutual potential for common synergies and benefits must be used.

FRM purports to reduce the likelihood and/or the impact of floods on human health, environment, cultural heritage and economic activity (Santato et al., 2013). In this context, EU member states should develop, periodically review and if necessary update plans for flood risk management with focus on prevention, protection and preparedness (EU, 2007). Prevention will be feasible via a suitable land use practice which prevents floods damage by avoiding construction of houses and industries in present and future flood prone areas, and by adapting future developments to the risk of flooding (EC, 2004). Furthermore, according to the European Spatial Development Perspective (1999), flood prevention in the major European river catchment areas can only be made effective through the imposition of explicitly defined conditions and intervention in land uses.

HFA along with FRD are two key policies for the protection of communities at risk (Bakker et al., 2013). “HFA for Action 2005-2015: Building the resilience of nations and communities to disasters” has been adopted in January 2005 by 168 governments during the World Conference on Disaster Reduction, held in Kobe, Hyogo, Japan and is about building resilience of nations and communities to disasters targeting to make the world safer from natural hazards substantially reducing the disaster losses, in lives and in the social, economic and environmental assets of communities and countries (UNISDR, 2007). HFA is essentially a global blueprint for disaster risk reduction, which provides guiding principles, priorities for action and practical means for achieving disaster resilience for vulnerable communities. It focuses on the development and strengthening of institutions, mechanisms and capacities to build resilience to hazards and it encourages the adoption of disaster risk reduction logic in sustainable development policies and planning as well as in emergency preparedness, response and recovery programmes (UNISDR, 2007). For the monitoring of the implementation of HFA, responsibilities are allocated to governments and also to regional and international organizations and partners in the United Nations International Strategy for Disaster Risk Reduction (UNISDR) secretariat. HFA is related to flood risk management, since floods are one of the main hazards, affecting annually millions of people all over the world (Bakker et al., 2013).

USE BY GOVERNMENT	BELGIUM (FLANDERS)	FRANCE	SWITZERLAND	NETHERLANDS	GREAT BRITAIN	ROMANIA	SLOVAKIA	HUNGARY	IRELAND	LITHUANIA	CZECH REPUBLIC	SLOVENIA	GERMANY	SPAIN	ITALY	FINLAND	AUSTRIA	LUXEMBOURG	POLAND	NORWAY	PORTUGAL	SWEDEN	LATVIA
Emergency Planning			*	*		*	*	*		*	*	*		*		*			*	*	*	*	*
Spatial Planning (Advisory)					*			*	*							*	*	*		*	*	*	*
Spatial Planning (Binding)		*	*			*				*			*	*	*				*				
Construction		*	*										*			*							
Awareness		*		*	*	*		*	*		*		*			*		*			*		
Insurance	*				*																		
Flood assessment/ management	*			*			*		*							*					*	*	

Table 1. Flood maps and their uses for flood safety in European countries (where information is available).

2.2 Flood maps and safety practices in Europe

Flood maps are developed by several institutions for a variety of purposes mostly used by the governments for emergency planning (e.g. evacuation) and spatial planning (De Moel et al., 2009). At the European level, some countries use spatial planning for advisory purposes and some other have binding legislation to employ flood hazard or risk information. The full potential of regulating land use in flood prone areas is often not reached as in many countries flood zones only serve as guidelines or there are practical problems associated with the implementation of binding rules (Santato et al., 2013; De Moel et al., 2009). Except from the planning purposes, flood maps are also utilized in raising awareness, in water management purposes, in flood assessments as well as in the insurance industry. The focus of different European countries in respect to flood safety for which flood maps are utilized is tabulated below (see Table 1).

3. THE DUTCH PERSPECTIVE TO FLOOD SAFETY

For over a millennium, people in the Netherlands have been both fighting against and enjoying the benefits of water from the sea, the major rivers Rhine and Meuse, precipitation and seepage of groundwater (De Lange et al., 2014; Ven, 1993). The Netherlands is considered as one of the safest deltas in the world, largely focusing on the flood prevention through its defense system. However, an evaluation of the water safety policy demonstrated that the country is not prepared for extreme flooding (Kolen et al., 2012). In addition, risk analysis for the Netherlands in 2008 (BZK, 2008) and 2009 (BZK, 2009) demonstrated that although a flood disaster is “highly unlikely”; it is the disaster type with the most catastrophic consequences in case of occurrence. For this, the multi-layered safety concept, which is currently the Dutch perspective to flood safety, is introduced and analyzed.

3.1 The multi-layered safety concept for flood risk management

As a response to the EU FRD, the Netherlands in its National Water Plan 2009-2015 has introduced the multi-layered safety concept, which bases on the widely adopted recommendations of both the FRD and the UNISDR’s HFA. In essence, the multi-layered safety concept is a three-tier approach to flood risk management (Gersonius et al., 2011),which integrates measures for reduction of probability and mitigation of loss in a flood protection system (Tsimopoulou et al., 2013). Multi-layered safety reinforces flood protection and operationalizes flood resilience by distinguishing three safety layers: (1) prevention; (2) spatial solutions and (3) emergency response (Hoss, 2010; Tsimopoulou et al., 2013; Gersonius et al., 2011; Van Herk et al., 2014). It is both a risk-based and a resilience-based approach as it focuses not only on the reduction of the probability of flooding via preventive measures such as dikes reinforcement but also on the reduction of the consequences of flooding (e.g. human fatalities and economic losses) through spatial measures and preparedness for emergency response (e.g. emergency management plans) (Rijke et al., 2014; Hoss, 2010). Such a framework has been developed in Belgium’s Flanders (Cauwenberghs, 2013). In USA and Canada (see for instance Lopez, 2009; Lopez, 2006 and Fraser Basin Council, 2008 respectively) similar approaches are used but called “multiple lines of defense” (Kolen et al., 2012).

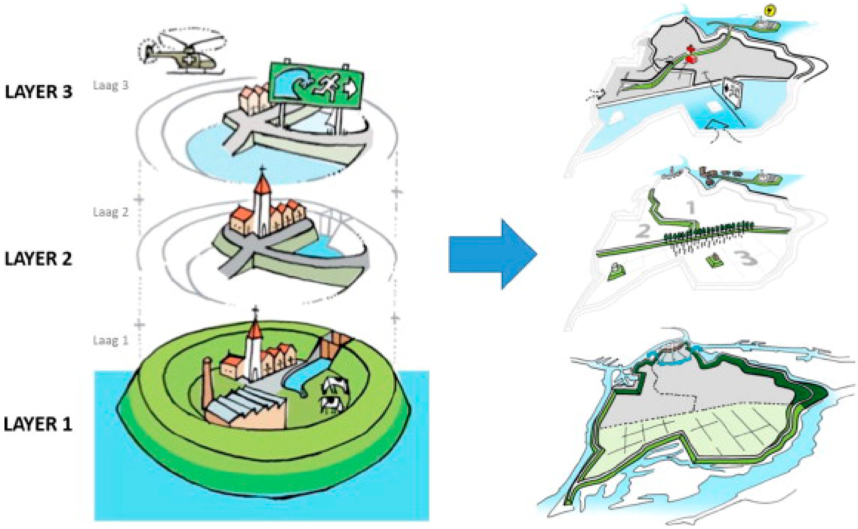


Figure 1. The three layers of the Dutch multi-layered safety concept which reduce the probability of floods (layer 1) and their consequences in case of occurrence (layers 2 and 3) (Rijke et al., 2014).

The three layers of the multi-layered safety (Figure 1), which forms an integrated flood risk approach, are presented below (Hoss, 2010; Tsimopoulou et al., 2013). The first two layers are physical measures while emergency response focuses on institutional (organizational) measures taken before the event (Hoss et al., 2011).

Layer 1: Prevention

This is about preventing rivers and seawater from inundating areas that are usually dry by constructing flood defenses or preventing high river discharges.

Layer 2: Spatial Solutions

These are pro-active measures focusing on the decrease of loss in the case of a flood occurrence by spatial planning, adaptation of buildings and protection of vital infrastructure. Solutions include location of urban and industrial land uses in areas with lower flood risk, raise of the constructions' ground levels etc.

Layer 3: Emergency Response

This focuses on flood emergency preparedness by setting the organizational framework of the emergency response as well as by developing evacuation plans, early warning systems, temporary physical measures such as sand bags and medical treatment.

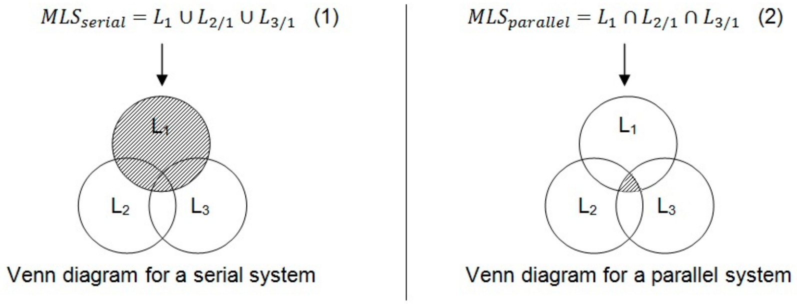
In the Netherlands, multi-layered safety is considered a shift from the past, where attention was traditionally paid on the first layer of flood prevention: the exploration of the potential of sustainable spatial planning and emergency preparedness, whose measures are intended to be tailored to local areas for minimizing the magnitude of the flood damage in case of such an event. However, multi-layered safety makes the task of water security more complex, as it is broader in scope and it requires multi-actor based work across multiple locations (Gersonius et al., 2011). While only Rijkswaterstaat (Directorate-General for Public Works and Water Management) and local waterboards are responsible for the first layer of dike rings, the second and third layers involve several parties including provinces, municipalities, safety regions and private parties, which call for a much higher level of coordination. Furthermore, the complexity of multi-layered safety lies in the need to account for future changes such as population increase or decrease, changes in economic and spatial developments.

3.2 Analysis of the multi-layered safety system

The Dutch shift from a predominantly prevention policy to multi-layered safety implies alteration of the flood risk management from a serial to a parallel system (Hoss, 2010). Furthermore, Jongejan et al. (2012) mention that multi-layered safety represents the relationships between the different phases or strategies as a parallel system rather than a serial system, which means that the different layers are not as weak as the weakest link fact that is falsely described by the safety chain concept. In this context, multi-layered safety requires interventions across its three layers to effectively reinforce the overall system's resilience to floods (Rijke et al., 2014; Gersonius et al., 2011). Hoss (2010), concluding that there will never be absolute safety, suggests implementation of multi-layered safety with respect to optimal allocation of resources instead of attempting to achieve maximum security at any price. Rijke et al. (2014) state that it is more efficient to invest in the layer(s) with the highest return on investment and to skip or minimize the use of the other(s).

$$MLS_{serial} = L_1 \cup L_{2/1} \cup L_{3/1} \quad (1)$$

$$MLS_{parallel} = L_1 \cap L_{2/1} \cap L_{3/1} \quad (2)$$



where:

L_1: Failure of Layer 1 (prevention);

$L_{2/1}$: Failure of Layer 2 (spatial solutions) given the failure of Layer 1 (prevention);

$L_{3/1}$: Failure of Layer 3 (emergency response) given the failure of Layer 1 (prevention).

Figure 2. Failure of the multi-layered safety concept as a serial vs. a parallel system. (Adapted from Tsimopoulou et al., 2013).

For the description of how the multi-layered safety system will function as a serial vs. a parallel system in case of a flooding, equations (1) and (2) are used and the respective Venn diagrams are employed for visualization purposes (Figure 2). As layer 1 is about reducing the probability of occurrence of flooding through preventive measures, in the case of flooding, layer 1 de facto fails. In a serial system, if one of its components fails, means that the whole system immediately fails. In a parallel system this fails only if all its three layers fail. In case that one or two out of its three layers fail, the entire system does not fail. However, for multi-layered safety, neither the one nor the other system definition can be valid, while currently a definition regarding this has not been indicated (Tsimopoulou et al., 2013). Jongejan et al. (2012) justify the latter by the following paradigm: If a levee system were to fail, less or more humans could be saved through emergency response, but the immediate damages could not be undone, nor could crisis response bring the immediate flood victims back to life.

In multi-layered safety, if Layer 1 fails leading to a flooding, Layers 2 and 3 can minimize the consequences of this flood event. However, the measures taken in multi-layered safety should not only focus on the reduction of either the flood probability or the damage in case of flooding, but on both parameters simultaneously. The explicit definition of failure in each safety layer in the form of exceedance of certain thresholds can significantly contribute to the management of multi-layered safety systems, as it introduces safety classification added in a system by means of decrease of flooding probability; reduction of environmental and economic damage and minimization of human fatalities (Tsimopoulou et al., 2013).

3.3 The need to methodologically frame the multi-layered safety concept

The multi-layered water safety concept more closely resembles a parallel system in which Jongejan et al. (2012) mention that it is more cost-effective to invest in one component rather than dispersing the available budget over all of them. From an economic perspective, attention should be paid on how the different investment strategies affect the probability of adverse consequences, based on the rational assumption that smaller losses are desirable over greater ones. However, local conditions could lead to different optimal balances between measures corresponding to the three layers of this multi-tier safety concept, i.e. between measures for flood probability reduction and damage minimization in case of flooding.

Economically speaking, beyond low cost investments in damage mitigation measures, how effective could heavy investments in this direction be? In 2007, Taskforce was established to improve disaster preparedness (TMO, 2009), considering strong investments in emergency planning, evacuation routes and equipment. The purchasing and maintenance costs of a fleet of aerial rescue means (helicopters) is enormous, taking into account that they will be rarely used on average to save some people from their rooftops. But even in this case the huge economic impact of a flood disaster and the inevitable injuries and human fatalities are unavoidable. In this situation, the minimization of the probability of flooding would be the more efficient strategy. Another example is the case of a flooding in a densely populated area, where an additional investment in prevention is likely to yield a far greater return compared to an additional investment in loss mitigation measures (Jongejan et al., 2012). However, in the case of Dordrecht city in which historic buildings line the existing flood defenses, Hoss (2010), in a comprehensive assessment of the multi-layered safety concept where he has explored how the flood risks can be reduced, identified that the improvement of emergency response preparedness or the flood proofing of buildings could yield better compared to the strengthening of the flood defenses (flood probability reduction). This happens due to the relatively high costs of reinforcing the flood defenses, considering the relatively small size of the area protected by them (Jongejan et al., 2012).

Cost-benefit analysis can be applied for structuring complex decision problems (Arrow et al., 1996), including safety regulations. However, the ability of cost-benefit analysis to produce morally relevant outcomes has been challenged, particularly for matters related to health and safety, where factors other than costs and benefits influence humans' moral judgments (e.g. Slovic et al., 2004; Slovic et al., 1984; Fischhoff et al., 1981). Hence, the results of a strict cost-benefit analysis should not be binding for the agency heads (Arrow et al., 1996). In this context, the multi-layered safety should not be driven only by economic factors focusing on the estimation of some efficient balance between safety and return.

Since there is no one single multi-layered safety policy, a framework such as geodesign, which takes into account the roles and values of the people at place and the principles of sustainability in a collaborative and interactive process for making balanced decisions, is required. In this context, this paper purports to geodesign the multi-layered safety, having in mind that collaboration and maximum consensus between the involved stakeholders has to be achieved for deciding the most desirable, balanced and sustainable safety measures. In the following sections geodesign is introduced and applied in order to methodologically systematize the multi-layered water safety concept, following a characteristic script of geodesign.

4. METHODOLOGICAL FRAMEWORK: GEODESIGN

Geodesign needs collaboration, which in turn requires organization that asks for a framework around which tasks can be identified and linked (Steinitz, 2012). In this context, the methodology of this study, i.e. geodesign is introduced and framed.

4.1 Geodesign: Definitions

The design of land uses in the context of geographic space and natural environment is not a recent concept (Paradis et al., 2013). The latterly dubbed geodesign has its roots thousands of years ago, being an interdisciplinary process of place making, where design has been variably affected by surrounding geographies and natural conditions (McElvaney, 2012). Goodchild (2010) supports that geodesign is not new; he states that it represents a re-examination and probably a repurposing of a number of established fields. However, Miller (2012) argues that unlike the activity of geodesign, the term is relatively new and only a small number of geo-related businesses have utilized geodesign as part of their name.

Dangermond (2009) sees geodesign as a systematic methodology for geographic planning and decision making, which employs all the geographic knowledge (layers of information, measurements and analytic models) that users collectively build, maintain and import into a new interactive process where one can design alternatives and acquire geography-based feedback on the consequences of these designs in a timely manner. Flaxman (2010a,b) defines geodesign as “a design and planning method which tightly couples the creation of a design proposal with impact simulations informed by geographic context”. Steinitz (2012) simply specifies geodesign as changing geography by design, where design related processes are developed and applied towards changing the geographical study areas in which they are utilized and realized.

The desire to change geography goes beyond individual buildings, looking at the broader scale plans towards better understanding and effect on the landscape (Artz 2010, 21). For the practice of geodesign, interdisciplinary collaboration between the design professions, geographical sciences, information technologies and the people at place is a must (Steinitz, 2012).

Paradis et al. (2013) explore the various definitions of geodesign. They identify that the integration of geographic sciences and geo-spatial technologies with design, which facilitates digital geographic analysis to inform the design processes, is the fundamental characteristic of geodesign. Fully leveraging geography during the design process can result in designs that emulate the best features and functions of natural systems, where humans and nature are mutually benefited via a more peaceful and synergistic coexistence (Artz 2010b, 16). In this regard, Dangermond (2010) sees geodesign as "designing with nature in mind" (Artz 2010b, 6). Furthermore, Ervin (2011) mentions that "geodesign enhances the traditional environmental planning and design activities with the power of modern computing, communications and collaboration technologies, providing on-demand simulations and impact analysis to provide more effective and more responsible integration of scientific knowledge and societal values into the design of alternative futures".

4.2 Geodesign framework and models

Steinitz' framework for geodesign is illustrated in Figure 3 (Steinitz, 2012). It was previously known as framework for landscape planning (Steinitz, 1995); it employs six questions that can be answered by six models for the description of the overall geodesign process (Steinitz, 2012).

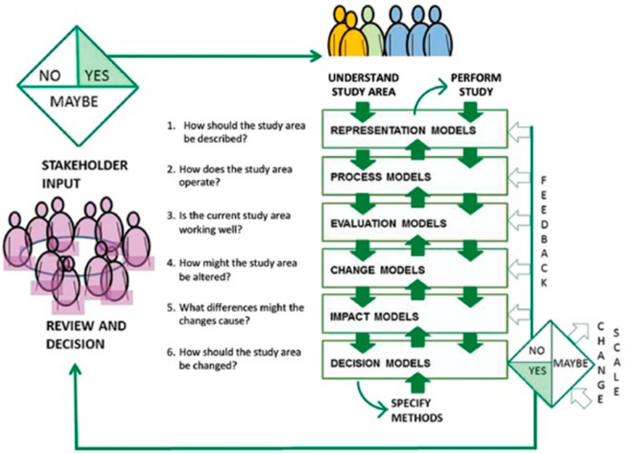


Figure 3. The geodesign framework (Steinitz, 2012).

The first three questions refer to the past and the existing conditions of the study area within a geographic context, while the last three are about the future more than the past and the present. The first three models, used for answering the first three questions, comprise the assessment process, while the last three models used comprise the intervention process respectively (Miller, 2012). The geodesign concept, through its six questions, provide a rapid, holistic, participatory, interactive and adaptive process for developing a more sustainable future (Dangermond, 2010). Furthermore, it enables the design of various alternatives, their evaluation in terms of impact on the natural environment as well as their utility to the human population, and selection and implementation of the alternative that is projected to achieve the best balance, thus supporting the development of the most educated and informed decisions about the future (Dangermond, 2009).

During a geodesign study, three iterations of the six questions of the geodesign framework (Figure 3) are explicitly or implicitly performed at least once before a decision towards implementation can ever be reached (Steinitz, 2012). In the first iteration where the questions are asked in a sequence from 1 to 6, the geographic study area as well as the context and the scope of the study are intended to be identified answering why the study should take place. In the second iteration, where the questions are asked in a reverse sequence, i.e. from 6 to 1, thus making geodesign decision-driven rather than data-driven, the methods of the study are intended to be selected and defined, simultaneously answering to the how questions. In the third iteration, the methodology designed by the geodesign team during the second iteration is carried out and, having data as a central concern, the study is implemented and results are provided. At this stage, the questions are asked from top to bottom, i.e. from 1 to 6, attempting to identify what, where and when.

Dangermond (2010) sees this iterative design/evaluation process as the way in which the human brain operates, i.e. try something, evaluate the results and move on. In order for the stakeholders to come to decisions, questions must be asked and answered and options for selection must be framed and deliberated. In short, the geodesign framework can be seen as a collaboration facilitator as well as a valuable support in the organization and solving of large and complex design problems, often at geographic scales, ranging from a neighborhood to a city, from the local to the national and even international level.

5. GEODESIGN THE MULTI-LAYERED SAFETY CONCEPT: THE CASE OF THE NETHERLANDS

Firstly, the information needs for the multi-layered safety concept in the Netherlands are explored. Afterwards, geodesign is theoretically implemented to present a framework for developing shared understanding of the current situation of an area of interest in terms of flood safety, as well as for achieving collaborative selection of the optimal multi-layered safety measures. The latter is accomplished by taking into account the values of the people at place, economic efficiency and environmental impacts of alternative safety measures in an attempt to achieve maximum consensus between the stakeholders.

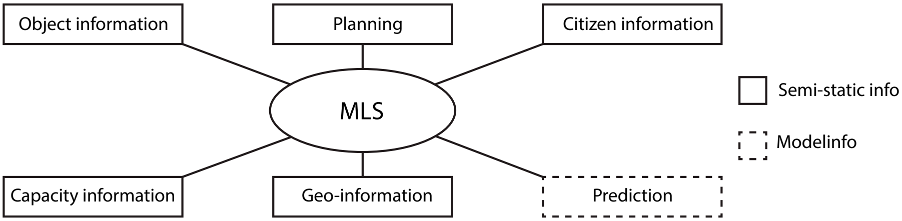


Figure 4. Overview of the information categories needed for the multi-layered safety concept (Adapted from ACIR, 2005).

5.1 Information needs

In order for a study area to be described, information is needed. The information requirements as described by ACIR (2005) for the multi-layered safetycan be determined as semi-static and model information. Furthermore, these information components are clustered into 6 different categories (Figure 4). However, when measures such as preventive organized evacuations are decided in the context of the emergency response layer, their implementation needs dynamic information. This is related to the (simulated) escalating flood and its effect on the incident location and the surrounding environment (geographical awareness), the capacity and the activities of the emergency response organizations to tackle it and normalize the situation.

In Table 2, an overview of data required for the multi-layered safety concept in the case of the Netherlands is provided. Almost all of these data have a spatial (geographical) component.

TEMPORAL NATURE	DATA	DETAILS	
SEMI-STATIC	Topographic data	Top10NL: Open topographic data (Street networks; Railroad networks [Rail, metro and tram lines]; Water bodies [rivers, sea, lakes, etc.]; Building footprints; Terrain [grassland, arable land, etc.]; Design elements [noise barriers, trees, pylons, etc.]; Relief elements [land contour lines, sea depth lines, etc.]; Geographical and functional areas [neighborhoods, campgrounds, etc.]) that can be used at scales between 1: 5.000 and 1:25.000 throughout the Netherlands.	
		BAG - Basic registration of Addresses and Buildings (In Dutch: Basisregistraties Adressen en Gebouwen): Open geodata about building footprints and addresses.	
	Elevation data	AHN2 - Actual Height Data (In Dutch: Actueel Hoogtebestand Nederland): Open, detailed and precise elevation data (terrain, building and vegetation information) of 0.5 m x 0.5 m resolution. Digital Terrain Model (DTM) and Digital Surface Model (DSM) can be extracted from AHN2 providing terrain and objects' height information respectively.	
	Flood defenses' specifications	Location, technical characteristics (e.g. capacity, cross-sections) of primary and regional flood defenses protecting from open (North Sea, Wadden Sea, rivers, IJsselmeer and Markermeer) and inland water (lakes, streams, canals) respectively. These include weirs, barrages, sluices and dams, which regulate water levels by water intake or releasing water when needed as well as dikes (floodgates or levees), natural sand dunes and storm surge barriers, which manage or prevent water flow into specific land regions. Topographic information about the flood defenses at scale 1:1.000 can be retrieved from DTB – Digital Topographic Database (In Dutch: Digitaal Topografisch Bestand).	
	Soil composition	GeoTOP from TNO – Dutch Organization of Applied Scientific Research (In Dutch: Nederlandse Organisatie voor Toegepast-Natuurwetenschappelijk Onderzoek): Detailed three dimensional (3D) model of the subsurface of the Netherlands, which is divided into voxels of 100 m x 100 m resolution. Information regarding stratigraphy, lithology and uncertainty of the voxel appearance is included. It is currently available for the provinces of Zeeland and South-Holland. For the multi-layered safety concept, emphasis is placed on the composition of the primary and regional flood defenses.	
	Water bodies data	Water depths at different locations from the Normal Amsterdam Level (In Dutch: Normaal Amsterdam Peil [NAP]). NAP is also the Dutch point for altitude measurements (m).	
		Flow rates (m3/s) of water in natural and manmade open channels. Flow rate (m3/s) of the seawater.	The water services (In Dutch: Waterdienst) of Rijkswaterstaat and the regional waterboards can provide such information.
		Cross-sectional characteristics of the water-bodies.	
	Precipitation and evapotranspiration data	Time series of rainfall (mm) during a day, rainfall intensity (mm/h), evaporation (mm/day), transpiration (mm/day) and evapotranspiration (mm/day) for areas (ha) at different locations. This information can be derived from STOWA Meteobase, the foundation of applied water research (In Dutch: Stichting Toegepast Onderzoek WaterBeheer).	
	Sewerage system specifications	Technical and geographical specifications of the system and its components (e.g. drains, manholes, pumping stations, screening chambers, storm overflows). Emphasis is placed on the collection of the storm water runoff. Regional waterboards and Rijkswaterstaat water services can provide such information.	
	Flood risk data	Risk map (In Dutch: Risicokaart): Vulnerable objects exposed to flood hazards and guidelines for emergency preparedness in case of different inundation depths.	

	Population	Numbers for every postcode district. (Derived from CBS - Central Bureau of Statistics (In Dutch: Centraal Bureau voor de Statistiek).	Inhabitants, density, growth, age, sex, disabled.
	Land uses	LGN6 - Nationwide Land Uses (In Dutch: Landelijk Grondgebruik Netherlands).	A grid file which distinguishes 39 land uses with a spatial resolution of 25 m x 25 m). Its main classes are urban, forest, water, nature and agricultural crops.
		Derived from CBS.	Land uses per municipality for different chronologies with their coverage in hectares (ha).
	Emergency capacity	Number and capacity of rescue means (ground and aerial) and emergency responders, classified per emergency organization (e.g. Fire brigade operational staff [professional and voluntary] provided by CBS). Location, number and capacity of emergency relief centers categorized by their function (e.g. medical aid, sheltering, catering, animal welfare), as well as by municipal area.	
	Financial indicators	Flood defenses.	Unit (construction, improvement and maintenance) cost, per type and function.
		Security care.	Material costs, per emergency response organization.
			Personnel costs (per capita spending), per emergency response organization.
MODEL	Prognosis data	Land-use forecasts. Flood forecasts based on different inputs and model parameters.	

Table 2: Flood maps and their uses for flood safety in European countries 2(where information is available).

5.2 Implementing geodesign on the multi-layered safety concept

In this study, geodesign is used as a theoretical framework in its conceptual form (Table 3) to shed light on involving stakeholders in the identification of the most desirable water safety measures, taking into account their socioeconomic and environmental impacts. The utilization of a geodesign framework purports to increase the effectiveness of the multi-layered safety concept, even though effectiveness is a broad concept which can include many aspects. In addition, through its models and iterations it intends to enable communication of stakeholders' values. In theory, by geo-designing the multi-layered safety concept, integration and exploration of ideas with direct evaluation at the same time is intended to be enabled. Furthermore, as geodesign is underpinned by trial and error logic, it increases the opportunity for experimentation and learning by doing (Steinitz, 2012).

GEODESIGN THE MLS	**FIRST ITERATION (WHY?)**	**SECOND ITERATION (HOW?)**	**THIRD ITERATION (WHAT, WHERE, WHEN?)**
1. How should the study area be described? *Representation models.*	What is the location of the Area of Interest (AoI)? How does the hydrologic system function in this AoI? What are the physical, economic and social activities in the AoI?	Where exactly is the study area and how is it bounded in hydrologic terms? Which data are needed? At what scale, classification, and times? From what sources? At which cost? How to be represented?	Acquire the required data (an overview is provided in Table 2). Analyze and visualize them over time and space using appropriate technology (multi-scale Geographic Information Systems [2D, 3D, 4D]). Organize them according to the needs of the three safety layers. Communicate them to the interested MLS parties using relevant (geo-) technology instruments (e.g. touch table [see below]).
2. How does the study area operate *Process models*	• What are the major hydrological processes in the AoI? How are these processes affected by precipitation and evapotranspiration, infiltration and percolation? • How are the surface and the sub-surface systems linked in the AoI? • How are the flood defenses functioning in the AoI? What is their capacity?	• Which hydrological processes should be considered in determining MLS policies and measures? • At what scale and for which time horizon should the safety measures operate? • What should be the level of complexity of the process models (for describing the AoI) that fit the purpose of the MLS study?	• Implement, calibrate and test the selected hydrologic models (stochastic; process-based models) for the AoI. Change the model parameters and run them several times. • Explain how the model outputs pinpoint the need to focus on one or more safety layer(s).
3. Is the current study area working well in terms of flood safety? *Evaluation models.*	Have high water depths been recorded in the AoI? Why? Are there currently problems with the functioning of the flood defenses? Why? Where? Are there developments in zones of high flood risks? How will they be tackled in the future spatial plans? Are the people at place aware about these problems? Are they prepared? Are the emergency agencies prepared to respond?	What are the evaluation criteria for the alternative safety measures corresponding to the three MLS layers? Economic? Legal? Societal? Environmental? What are the measures for evaluation of the success in terms of prevention (flood probability reduction), loss minimization through spatial solutions and emergency preparedness in the case of flooding?	Evaluate the flood safety condition of the AoI based on defined thresholds. Visualize and communicate the results. Explain how the local socioeconomic activities as well as environmental factors affect the flood safety in the AoI. Evaluate the current safety measures taken in the AoI, identify their effectiveness and classify them according to the three safety layers. Identify whether a reinforcement of the current measures or a shift is needed in the context of the MLS.
4. How might the study area be altered in order to meet the flood safety requirements? *Change models.*	In which of the three safety layers will the weights be placed? What are the alternative scenarios? Is visualization needed? How will the AoI meet the flood safety requirements in the future? Will it be a shift from the current practice? How?	What is the time horizon and scale(s) for the alternative safety measures? Are there any assumptions and requirements for them? What change model(s) will they be used to describe the future alternatives in terms of flood safety? Will the outcomes be simulated and/or visualized?	Example of alternative measures that can be visualized. Participants can propose more.

5. What differences might the changes cause in terms of cost- efficiency? *Impact models.*	What is the impact of the alternatives in terms of cost-efficiency? Are measures related to the reduction of flood probability more beneficial compared to measures related to consequences reduction in case of flooding? Why?	Are the economic impacts of the possible safety measures related to the three MLS layers regulated by legislation or regulations? How? Which impacts even if they are cost-effective should be assessed from a legal and/or environmental perspective?	Perform a cost-benefit analysis for the alternative measures corresponding to the different safety layers of the AoI. Identify and rank the most cost-effective. Visualize and communicate the results. Compare and explain the impacts of the measures corresponding to the different safety layers in terms of cost-effectiveness.
6. How should the study area be changed in order to meet the flood safety requirements, taking into account moral factors and values of the local society, cost-efficiency of the safety measures and the impact of the measures on the environment (principles of sustainability)? *Decision models.*	What is the main purpose of the study? Is it more efficient to invest only in the layer with the highest return in economic terms? Is it socially acceptable? Who are the major stakeholders and what are their positions, if known? Are there any binding technical and/or legal limitations for the AoI that must guide the MLS study? Are there any identified implementation difficulties for any of the measures related to the three layers of the MLS?	Who will make the decisions and how? What do they need to know? What will be the basis for their evaluation? Scientific? Cultural? Legal? Ethical? Combination of the previous? What should the decision makers consider as failure of the safety layers? Are there issues related to the implementation of the safety measures in terms of cost and technology?	Check whether the more cost-effective alternative measures, corresponding to the three safety layers of the MLS, are morally relevant and thus more likely to be socially acceptable. Check whether these measures have any side effects on the environment. Select a number of safety measures in a multi-disciplinary driven context, taking into account their economic efficiency, the values of the people at place and their environmental impacts and decide upon their suitability: • No, which implies more feedback; • Maybe, which means that further study at different temporal and spatial scales is required; • Yes, which drives to the presentation of the most suitable safety measures to the stakeholders for their decision and possible implementation.

Table 3: Theoretical implementation of geodesign on the Multi-Layered water Safety concept (MLS).

The results of framing the multi-layered safety in the context of a geodesign study are tabulated (Table 3). At the end of the process, the stakeholders can say no, maybe, or yes to the alternative safety measures. No, implies that the proposed safety measures do not meet their requirements; maybe can be treated as feedback, and calls for changes possibly in the allocation of the weights regarding the three safety layers; yes means implementation of the proposed safety measures. The latter will be used as data in the updates and future reviews of the multi-layered safety measures through the proposed framework. The route for coming into an agreement regarding the most suitable, desirable and balanced safety measures is not straight forward and normally non-linear, as many entries of different types and of different sources may be received, leading to revisit and revision of the decisions.

Moura (2015), based on her empirical study, mentions that the use of geodesign framework has proven to be a system in an open box that establishes steps, presents partial results, composes potential changes and choices, simulates alternative scenarios and possibilities, determines responsibilities, and limits of what is acceptable based on societal values and urge people to decide about their common future, employing a shared way of communications and ideas exchanging. In this line, it can be said that geodesign is not a linear process, as it contains feedback loops for model adjustments towards identifying optimal solutions. Stakeholders' involvement in the identification of the most favourable measures regarding the three layers of the multi-tier safety concept is needed to foster credibility in decision-making. In literature, some authors, including Batty (2013), Steinitz (2012) and Goodchild (2007), discuss how geo-technologies can support stakeholders' participation in geodesign. In particular, the potential of interactive geodesign tools in decision-making is increasingly acknowledged (Steinitz, 2012; Dias et al., 2013). For example, an interactive mapping device called "touch table" can be used as stakeholders' communication platform in the implementation of geodesign on the multi-layered safety concept, similar to previous studies (see Eikelboom and Janssen, 2015; Janssen et al., 2014; Arciniegas et al., 2013; Alexander et al., 2012). The added value service of a touch table, which includes for instance learning by experimenting, intuitive control and geo-spatial database availability, has been discussed in several articles (e.g. Pelzer et al., 2014; Pelzer et al., 2013; Eikelboom and Janssen, 2013; Arciniegas et al., 2011).

6. CONCLUDING REMARKS

In recent years there has been paid considerable attention to improving the flood protection in Europe and beyond. As a consequence, there was a growing need to share information and best practices in the field of flood risk management. In this context, the Netherlands has introduced the multi-layered safety concept for flood risk management, which is based on recommendations for flood protection such as the EU flood risk directive and the UNISDR Hyogo framework.

The multi-layered safety concept includes structural and non-structural measures representative of its three layers, which target to reduce the flood risk probability through prevention (layer 1), as well as the consequences in case of flooding, via spatial solutions and emergency response (layers 2 and 3). By analyzing a multi-layered safety system, it can be deduced that such a system resembles more a parallel than a serial one, as failure of the safety measures in one layer does not mean failure of the whole system. However, it is not exactly a parallel system, because when the preventive measures fail, the immediate consequences cannot be undone. The measures corresponding to layers 2 and 3 are able to reduce the damage, but not to completely eradicate it. Failure of the preventive measures is obvious when a flood occurs. But what is considered failure in layers 2 and 3 has to be explicitly defined, which will support the allocation of weights between the three layers of the multi-layered safety concept.

The goal to promote stakeholders participation and collaboration supporting decision making in regards to the most desirable and balanced water safety measures across different spatial and temporal scales has been achieved by theoretically orchestrating the multi-layer safety concept in a geodesign structure. A primary concern for the multi-layered safety concept is the inventory of the required data. Decisions, especially for matters related to flood safety, should rest on the firm ground of relevant and of high quality data. In this context, this contribution attempts to provide a first comprehensive overview of the data required for the multi-layered safety concept. However, questionnaire surveys with the participation of the involved to this multi-tier safety concept can shed more light regarding the information requirements of each safety layer. In this way, overlaps in terms of information needs between the three safety layers can be identified as well.

In order to develop and select optimal flood safety measures, all the stakeholders involved in the multi-layered safety concept have to develop awareness regarding the current water safety status in an area of interest. In particular, they have to comprehend the current functioning of an area of interest and also the way(s) in which flood safety is presently addressed. Furthermore, the stakeholders have to work together respecting each others values, considering local circumstances and searching for the most balanced and sustainable solutions. Cost-benefit analysis can extract the measures which can yield better from an economic perspective. However, in matters related to health and safety, human judgments are influenced not only by economic factors but also by ethical values. In this context, the systematization of the multi-layered safety concept, following the geodesign framework, creates surplus value for the local society, economy and environment through its different and iterative feedback-driven processes. The geodesign of the multi-layered safety concept motivates collaboration between the involved to the multi-layered safety parties without losing their identities. It underpins trial and error logic so that all stakeholders can assess the impact of the safety measures resulting from their own points of view. In this way, the stakeholders can identify overlaps in terms of the proposed measures which in turn can create maximum consensus between them, leading to the selection of the most desirable future water safety measures that considers their cost efficiency, their impact on the environment and the values of the people at place. But in order the geodesign of the multi-layered safety concept to be successful, it should be seen as useful by those working with it. If they intentionally deviate from the principles of this framework, the decisions, i.e. the safety measures can leave the stakeholders unsatisfied, because of which they will reject them.

Further research is needed towards transferring the implementation of geodesign on multi-layered safety from theory to practice. In particular, the geodesigned multi-layered safety concept should be experimented, tested and experienced in workshop settings and in different contexts for identifying optimal safety measures. Furthermore, during such workshops, technology driven tools, which empower society by enabling their participation in the decision-making, should be employed and assessed in the context of practicing geodesign in order to arrive at sustainable arrangements regarding water safety.

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Spatial tools for diagnosing the degree of safety and liveability, and to regenerate urban areas in the Netherlands

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Abstract

This contribution describes the tool Social Safe Urban Design (SSUD), seen together with socio-spatial and linguistic challenges when applying space syntax in the regenerating of problem urban areas. The Space Syntax jargon is technical and needs to be translated into a language understandable and acceptable to stakeholders who are responsible for the implementation of improvement strategies acceptable for the users of a neighbourhood. Moreover, the degree of public-private interface between buildings and streets needs to be incorporated in the Space Syntax analyses. As it turns out from spatial analyses and crime registrations, there is a correlation between crime and anti-social behaviour and the spatial layout of built environments in the investigated eight pilot cases. Simultaneously, there is also a challenge to come up with locally and globally functioning spatial solutions for reducing opportunities for crime and anti-social behaviour for the neighbourhoods. Proposed solutions for three of these neighbourhoods are presented in this contribution.

KEYWORDS

Space syntax; Urban regeneration; Network configuration; Crime; Communicative planning

1. INTRODUCTION

The past five years, several deprived neighbourhoods in the Netherlands have received special attention for improving their liveability, safety and socio-economic position. The main focus is on improving the social and economic position of the neighbourhood's inhabitants, the quality of the built environment itself and formal surveillance. As far as the built environment is concerned, the emphasis is primarily on the physical properties (such as renovating buildings and playgrounds) of the neighbourhoods, while the spatial properties are largely overlooked.

In this context, the project Social Safe Urban Design (SSUD) was conducted. This project resulted in a new tool for the (re)vitalization of new and existing residential neighbourhoods. The basis of this tool lies in a national survey, which was carried out in 43 neighbourhoods and in eight pilot neighbourhoods the approach was further refined and applied. In the Dutch municipalities of Alkmaar, Deventer, Eindhoven, Maastricht and Utrecht consultancy projects were carried out in which the researchers and local stakeholders worked together to draft recommendations and interventions for possible improvement of the liveability, safety and economic potential of the pilot areas. This contribution presents the SSUD project as an example of how space syntax can be applied in consultancy practices: how to make space syntax understandable and acceptable to the laymen and what challenges do we need to overcome to translate scientific knowledge into practical and feasible interventions.

2. INVOLVING THE STAKEHOLDERS

The specific agendas of the local stakeholders and policymakers need to be recognised for identifying what they consider as key issues for the neighbourhood. Mutual understanding and consensus need to be established and interactive workshops are a good way to achieve this (Forester, 1989; Arnstein, 1969). The challenge is to translate the space syntax jargon into a terminology understandable for the involved stakeholders who have a practical rather than a scientific interest in the problems at hand. This rhetorical approach implies in this case that the pathos (the words used) and logos (the correlation between safety, vitality and spatial configuration) in re-design proposals have to be understandable for all involved parties. Likewise, the ethos of the approach is to propose solutions that are both understandable for the users and that can reduce the opportunities for crime and ant-social behaviour (Asmervik, 1998). In this way, the local stakeholders feel an ownership to the plans as well as the feeling to have participated in a plan contributing to increase the safety and vitality of the neighbourhoods. The communicative approach is the project's button-up approach.

The analytical approach is a top-down approach, consisting of correlating crime data provided by the police with the space syntax analyses. The results were presented to the various policymakers and (other) stakeholders. In addition, fieldwork was carried out consisting of a registration of the quality of buildings, public spaces, location of shops and services, and parks in the area, the liveliness of the streets and implemented crime prevention measurements (such as the Dutch Police Label Safe Housing).

The results from the analytical approach were used to construct several improvement scenarios for the neighbourhoods. They were presented to the local stakeholders and discussed at redesign workshops. Various models for redesign were developed and tested both on their spatial properties, forecasted effects on criminal opportunity and feasibility. Together with the stakeholders it was then decided whether these models are in the neighbourhoods best interest and how they can best be translated into measures effective and feasible to implement.

3. THE CONCEPTUAL FRAMEWORK

The term accessibility is used to describe global as well as local angular integration with a topological radius. As space syntax research has shown, the higher the degree of accessibility of the street system on various scale levels, the higher the number of people in the streets (Hillier, Penn, Hanson, Grajewski, & Xu, 1998). Conversely, a lower degree of accessibility reduces the number of people in streets, resulting in less natural surveillance. Streets with a low degree of accessibility on a local level in particular tend to be affected by burglaries (Van Nes, & López, 2010; Hillier, & Sabaz, 2005).

With the evidence from various space syntax studies, the following two principles are used in the improvement strategies for the eight neighbourhoods. The higher the degree of street accessibility on the local as well as on the city level, the more it generates a mixture of visitors and locals on the streets. A balanced mixture of different user groups on the streets increases the degree of informal social control, which in turn reduces the opportunities for crime and anti-social behaviour and increases the feeling of safety.

The term connectedness is used in this project to describe how the main route system that is going through and between neighbourhoods is connected to all the local streets. The angular step depth analysis from space syntax provides insight in how a main route is connected to the local streets. When most dwelling streets are more than two direction changes, or more than one direction change with sharp angles from the main route network, the area scores low. When a main route is located outside the neighbourhood, the local streets tend to get extremely low values in the angular step depth analyses. Conversely, when a main route goes through the area, the local streets get high values. In these cases most streets of a neighbourhood can often be reached within two direction changes.

Research has shown that the higher the number of direction changes from the main route network, the higher the risks on burglary (Van Nes, & López, 2010) and anti-social behaviour (Rueb, & Van Nes, 2009). Therefore, the following principle is used in this project: the lower the number of direction changes from the main routes, the lower the burglary risk.

Vitality refers to the spatial potential for vital street life and successful local businesses. When a main route goes through the neighbourhood combined with high integration values, it contributes to the location of small businesses inside the neighbourhood (Hausleitner, 2010; Van Nes, Berghauser Pont, & Mashhoodi, 2012). When a main route is located around the neighbourhood, the neighbourhood tends to lack small businesses and the area consists of only dwellings (Yu ye, &, Van Nes, 2014). Especially the overlap between the angular analyses with high and low metrical radii appears to be important. When these two analyses do not correspond, the neighbourhood lacks the spatial framework supporting urban vitality. These neighbourhoods tend to lack street life and various facilities.

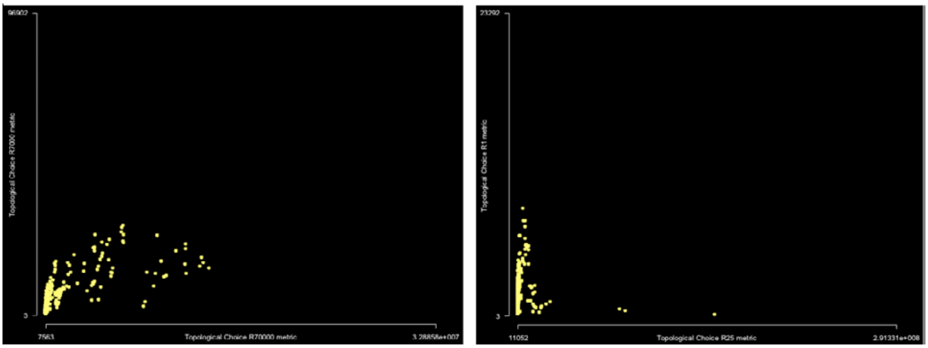


Figure 1. Two different scatterplots showing the correlation between the angular analyses with a high and a low metrical radius. The scatterplot to the left is from a vital neighbourhood where the scatterplot to the right is from a mono-functional problem neighbourhood.

Figure 1 shows a scatterplot of two different neighbourhoods. In the scatterplot to the right, the plots have an L-shape. In this case, streets with high values on the metrical high radius have low values on the metrical low radius and vice-versa. These neighbourhoods tend to lack street life due to the fact that the main routes are located outside the neighbourhood. Often these neighbourhoods tend to be very mono-functional, consisting of mostly dwellings. In the scatterplot to the left, the values correspond. Streets with high values on the metrical high analyses have also high values on the metrical low analyses. These neighbourhoods tend to have the main routes going through the area and to have micro-businesses located along these main streets.

It is important to explain to the local stakeholders and involved parties that a smart lay-out of the street network does not only limit the opportunities for crime and incivilities. It also shapes opportunities to improve the economic potential of the area and vital street life.

Visibility is about how visible the streets are from dwellings on ground floor level and how well dwellings are visible from streets (Van Nes, & López, 2010). The position of entrances and windows are plotted on maps, providing insight in the extent to which public spaces are directly visible to visitors and residents, and the location of visual barriers. The degree of visibility can be combined with the space syntax maps. Separate maps are made, providing insight in the extent to which public spaces are directly visible to visitors and residents, and the location of visual barriers. Regarding visibility, the following principle is used in this project. Both windows and doors located on ground floor level contribute to informal social control between people in streets and people inside buildings.

The identity of a neighbourhood – its character and atmosphere – is largely determined by the attractiveness of the neighbourhood, the aesthetic quality of the buildings and public spaces, the diversity of buildings, the clarity of the functions of the public spaces, the orientability of the route system for visitors, and attractive well maintained public facilities. The use of semi-public spaces almost always generates problems when the function or management of these areas is unclear (Luten, 2008). In determining the identity of a neighbourhood, data are collected on the quality and diversity of the buildings, the facilities provided, the amount and use of public parks and the level of maintenance and management. The following principles are used in this project: clarity of functions, an intelligible routing system and attractive well maintained public facilities contribute positively to the character and atmosphere of the neighbourhood.

4. GENERAL FINDINGS

The first phase of the Social Safe Urban Design (SSUD) project consisted of a national inquiry in which spatial, crime and social data of 43 deprived Dutch neighbourhoods were collected and analysed on the neighbourhood level (Van Nes, & López, 2013) and data of four neighbourhoods were studied in detail on the level of the street segment. This resulted in the model Social Safe Urban Design with various insights regarding the accessibility, connectedness, vitality, visibility and identity of neighbourhoods and their relation to the spatial distribution of crime and social parameters.

As it turns out, there are strong correlations between spatial accessibility and connectedness and crime dispersal inside the neighbourhoods. Street segments with poor values on accessibility, connectivity, vitality, visibility and identity are more often affected by crime and anti-social behaviour than streets with good spatial values. There are, however, examples of neighbourhoods (e.g. Oudegoedstraat in Deventer) where the technical standards of the dwellings are at such a high level that it overruns the poor spatial properties of the neighbourhood, keeping the number of residential burglaries low. With regards to the social composition of dwellers, it turns out that low-skilled non-European immigrants and low-income people tend to be clustered in neighbourhoods that score low on the spatial analyses concerning accessibility and connectivity (Rueb, & Van Nes, 2009)). How and in which way accessibility and connectedness relate to criminal dispersal depends on the type of crime. As Valerie Alford already concluded: ‘Different types of crime occur in different types of space’ (Alford, 1996, p. 64).

The national inquiry resulted in several statements that have been taken into account during the in-depth study of the eight pilot cases and in the definition of the urban renewal scenario’s and measures proposed to revitalize these areas:

- An integrated main route through the neighbourhood contributes to a natural mixture of visitors and inhabitants and to a mutual social control between them.
- Dwelling streets that can be reached within one to two times direction changes from main routes tend to have a lower burglary risk than dwelling streets with more than two times direction changes.
- Street with blind walls adjacent to services and local shopping centres contribute to a clustering of youngsters making noise and disturbances.
- Neighbourhoods with streets with low values on the local angular integration analyses with a topological radius tend to lack street life and location of small local businesses.
- Neighbourhoods with streets that have high values on the local angular analyses with both high and low metrical radii have lower incidents of vandalism and anti-social behaviour of youngsters than neighbourhoods where these aspects do not overlap.
- Streets with high spatial integration contribute to more people in streets and to the location of small businesses. These streets are perceived to be vital and social safe streets.

The studied eight pilot cases yielded the following findings in relation to criminal dispersal:

- Residential burglary mainly takes place in the streets furthest away from the main routes, most commonly in places with low degrees of intervisibility.
- Theft from cars is most common in streets close to the main routes, in particular on large parking lots.
- Threats and fighting are especially common in segregated streets with poor intervisibility.

- Physical abuse and threats generally take place in streets that are poorly connected to the main route network.
- Anti-social behaviour of youngsters generally take place close to service and shopping functions on streets adjacent to the main routes, and spots with poor intervisibility.
- Vandalism is most common along the main routes, at schools, youth centres and public transport stops/stations.

5. EIGHT PILOT CASES

The SSUD model and the findings of the national inquiry have been used to analyse eight neighbourhoods in five different Dutch municipalities, to develop scenarios and models for revitalisation, and measures to improve the safety and vitality of these neighbourhoods. The eight cases cannot all be described as deprived areas. They all have challenges with regards to vitality and some of them have social or criminal problems. During local workshops, a wide range of both radical and minor interventions were explored and discussed with the stakeholders. In this contribution only the final proposals are presented, which are the ones that according to all parties involved are both feasible and effective. The coming years will show which interventions are actually implemented and how effective they turned out to be.

The eight cases vary a lot in terms of the social composition of dwellers, building typology, building period and planning ideologies. Two of the neighbourhoods are yet to be built. The cases can be classified as: pre-war working class neighbourhoods (Rode Dorp in Deventer and Mariaberg in Maastricht), post-war housing neighbourhoods (Kanaleneiland in Utrecht, Pottenberg in Maastricht and Vaartbroek-Eckart in Eindhoven), and post-modern/new urbanism neighbourhoods (Hoge Weide in Utrecht and Vroonermeer-Noord and -Zuid). In this section, three of these neighbourhoods are described as an example of each category.

6. PRE-WAR NEIGHBOURHOODS

Rode Dorp in Deventer is a typical pre-war working class neighbourhood, housing a relative high number of poor immigrant and youngsters. In the spatial analyses, the area scores quite well. The area has gentrification potentials, due to its proximity to Deventer centre and provision of relatively integrated main routes running through the neighbourhood. Figure 2 shows the space and crime analyses of the Rode Dorp area. The most integrated streets have high values in the angular analyses with both high and low metrical radii. The accessibility of the main route Boxbergerweg is high. The main route Enkstraat and many residential streets are however not so well connected and therefore more vulnerable to crimes such as burglary, assault and vandalism. Many public functions such as playgrounds and squares are located at segregated streets poorly connected with the rest of the neighbourhood. Rode Dorp has several streets with blind walls and several unclear routings. The area has a strong place identity in the vernacular architecture of the buildings. Most of the buildings are small-scale row houses. In the south-western part, the area is disconnected to the surrounding neighbourhood due to the barrier formed by the rail track.

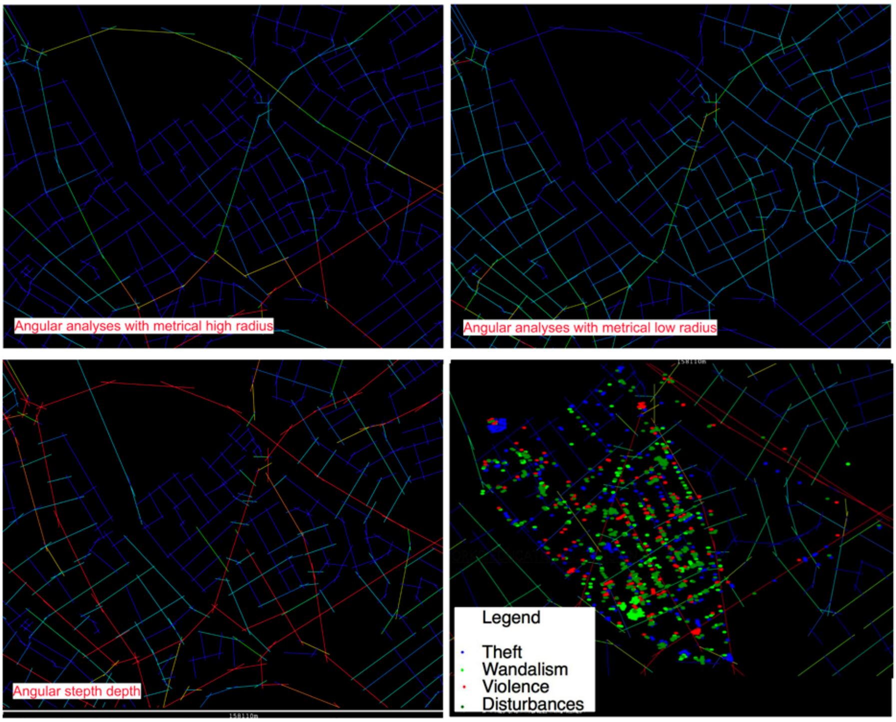


Figure 2. Space and crime analyses for Rode Dorp in Deventer.

To improve the safety situation in Rode Dorp and to create spatial potential for vital street life and small businesses, various design and urban renewal measures have been proposed. These measures focus on improving the vitality of the neighbourhoods' main route Boxbergerweg and the creation of a continuous cycle route along the rail track. Four different models have been proposed to increase the accessibility and connectivity of the three boroughs by linking several streets. On a micro-scale level, proposals are made to improve the visibility around the school, the youth centre and some of the squares and parks as well as the accessibility and visibility of the small playgrounds. As can be seen in Figure 3, the proposed changes increase the integration in the most segregated streets in Rode Dorp area.

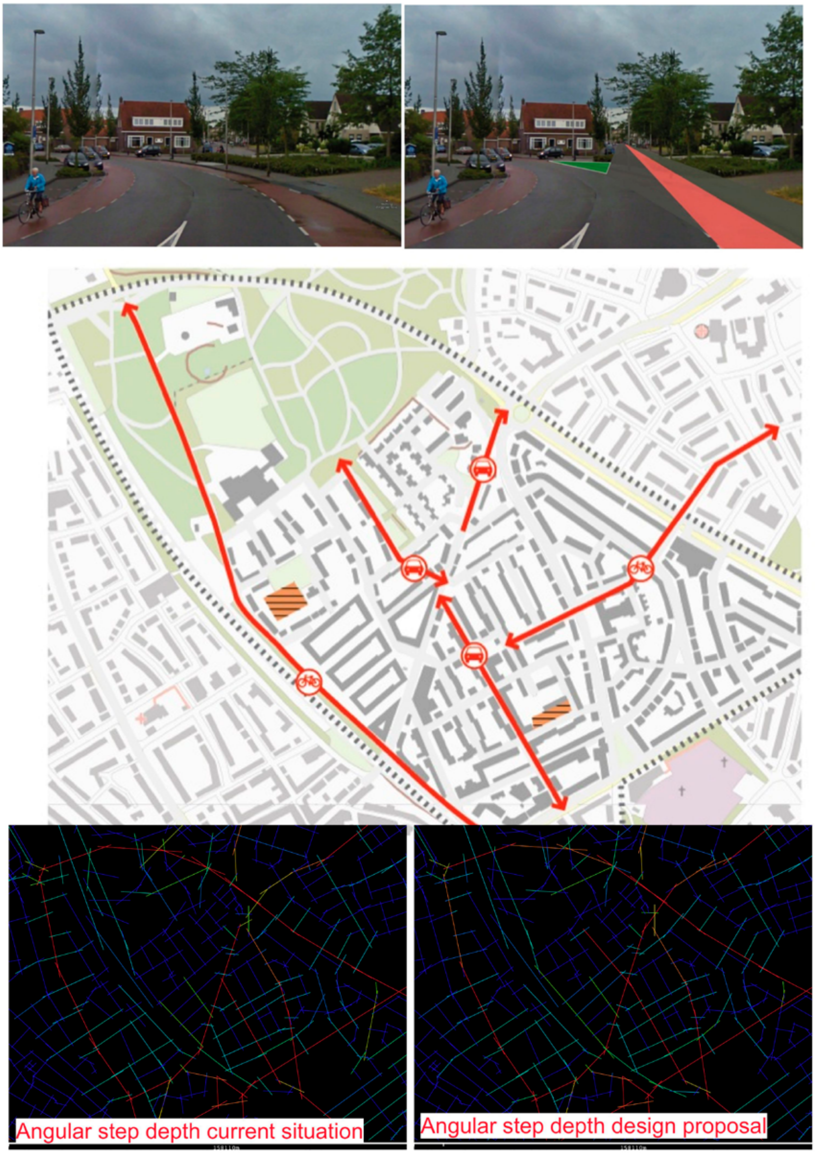
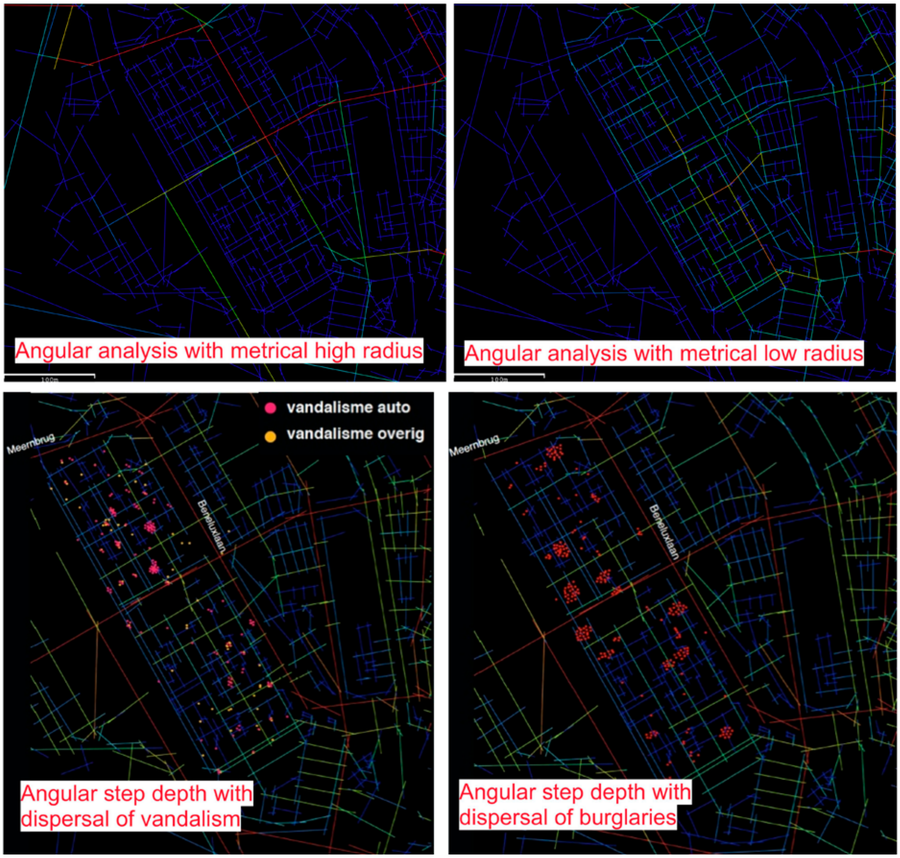


Figure 3. Improvement proposal for Rode Dorp in Deventer.

7. POST-WAR HOUSING NEIGHBOURHOODS

Kanaleneiland (Utrecht) is a good example of a Dutch post-war modernist urban area. Its socio-demographic and economic position is weak and the spatial characteristics are poor on almost all investigated variables. The neighbourhood consists of two areas divided by a road.



Angular analysis with metrical high radius

Angular analysis with metrical low radius

Angular step depth with dispersal of vandalism

Angular step depth with dispersal of burglaries

Figure 4. Space and crime analyses for Kanaleneiland in Utrecht.

Figure 4 shows the space and crime analyses of the Kanaleneiland area. The main routes in Kanaleneiland are mainly located around this neighbourhood. The main route between Kanaleneiland-North and -South has high integration values. The area has a grid structured street pattern which is broken up, due to a high number of T-junctions inside the area. Therefore, the various residential streets have low values in the angular step depth analysis. The local shopping centre in the area's southern part is located along streets with high values in the angular analysis with a low metrical radius, whereas the large inward oriented shopping centre for the northern part is located along the main route with high values in the angular analyses with high metrical radius. The dwellings in Kanaleneiland have their entrances on the most segregated streets in the area. The area has several playgrounds, but these are mostly located in segregated streets with little or no intervisibility. Several of the playgrounds and the parking garages look deteriorated.

The key to improve the spatial conditions of Kanaleneiland is to reconstruct the neighbourhoods' broken up orthogonal grid structure. This grid structure has been broken up at several points over the last few decades, mainly at the hand of traffic engineers who reasoned it would be safer for pedestrians and bicycle riders when some streets were no longer fully accessible for motorized vehicles. The proposal for improving the spatial conditions in Kanaleneiland consists, therefore, in strengthening the main routes through the area. First of all, there is a need to make an internal main route in a north-south direction through the area, linking the northern and southern part of the area together. This route has to be well connected to the east-west oriented main route, which currently divides the area. The connection to surrounding neighbourhoods must also be enhanced and the same goes for the connection between local dwelling streets and the main routes. Figure 5 shows the spatial analyses of the design proposal. On a lower scale, the pedestrian accessibility between the northern and the southern part needs improvements. There are some new buildings adjacent to the east-west main route, but they lack active frontages towards this main route.

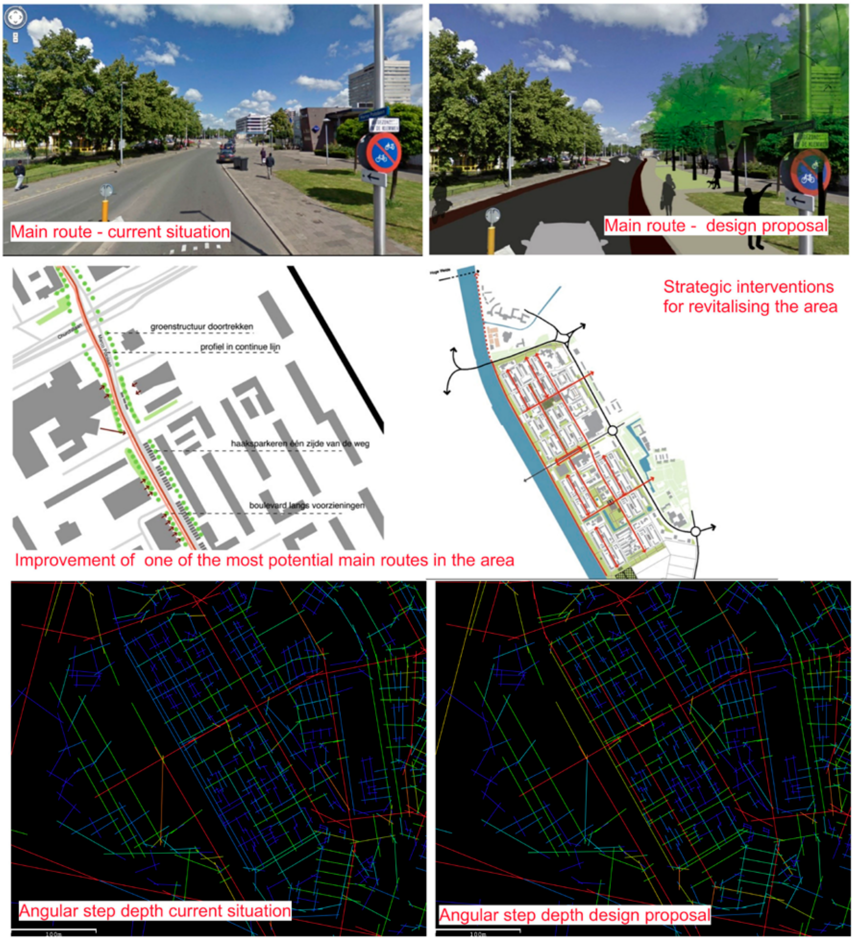


Figure 5. Improvement proposals for Kanaleneiland in Utrecht.

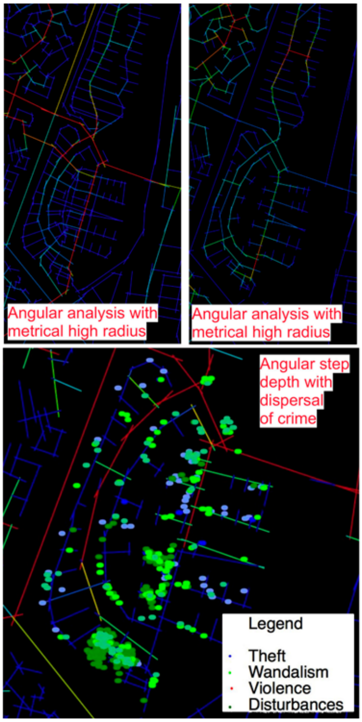


Figure 6. Space and crime analyses for Vroonermeer-Zuid in Alkmaar.

8. THE POST-MODERN/NEW URBANISM NEIGHBOURHOODS

Vroonermeer in Alkmaar is an example of contemporary urban design practice in the Netherlands. The first part of this neighbourhood – Vroonermeer-South – was completed in 2005 and consists of 1,230 homes. Vroonermeer-North is yet to be built. Like many other post-modern neighbourhoods, Vroonermeer is designed as a low-traffic residential area. The existing housing area and the new plans of the Vroonermeer-North consist almost entirely of residential houses. Vroonermeer-South only has one side access point for motorized traffic. The routes for cars, bicycles and pedestrians are largely separated and the streets accessible for motorized vehicles are blocked at two places leading to a highly segregated street pattern, offering poor accessibility between the neighbourhoods and its surroundings. As the spatial analyses of Vroonermeer-South shows in Figure 6, there are several spatial issues on various scale levels. The spatial characteristics of the proposed plan for Vroonermeer-North are much better than Vroonermeer-South. There is no separation between fast and slow traffic. The borough is accessible from both the north and south and vehicles can move through this area. In general, Vroonermeer-North's street pattern is better connected with the urban network than Vroonermeer-South. The main route running through the centre of this borough is fully accessible and well connected (Figure 7).

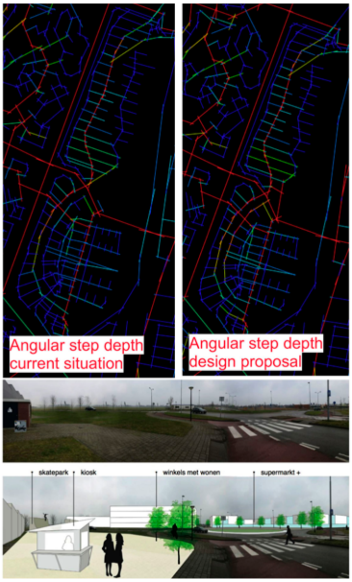


Figure 7. Improvement proposals for Vroonermeer-South in Alkmaar.

There are several issues concerning visibility. Several houses both in North as South turn themselves away from the main routes and green spaces. The orientation of the buildings, the lack of meeting places and the low accessibility do not provide spatial qualities that strengthen the bond between the residents. The streets are relatively quiet. There are almost no visitors from outside the neighbourhood and the residents themselves have no reason to stroll the streets. The level of crime is still relatively low in Vroonermeer, probably due to the social composition of dwellers. Many of the residents are hardworking commuters. There are many children in the neighbourhood, but still few teenagers. In ten years' time this may of course all be different. The most pressing challenges at this moment are lack of street life inside the area and scarcity of commercial and service functions.

To improve this situation various strategies and measures have been proposed (Figure 8). These strategies focus on making some routes accessible for vehicles, improving the accessibility of Vroonermeer-South, making spatial and physical changes for improving the vitality of the neighbourhood, and creating a new local centre connecting the two boroughs together instead of separating them.

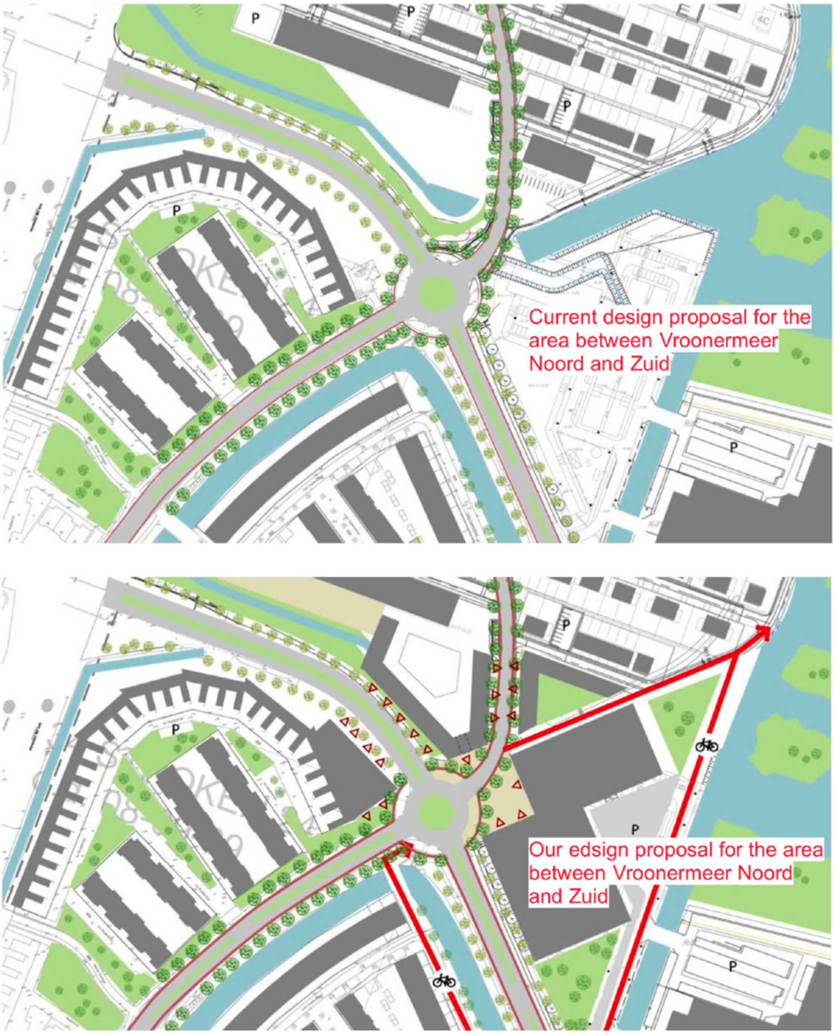


Figure 8. Plan for a new local centre between Vroonermeer-North and -South.

9. CONCLUSIONS – NEW CHALLENGES FOR URBAN REGENERATION PRACTICES

How to improve the use of space syntax in urban regeneration, urban planning and design practice? During the last few decades, space syntax has grown and been accepted by many scholars worldwide as a method not only suited for describing the spatial properties of the street network, but also as a tool for predicting the effects of possible changes. As such, space syntax is well suited as a tool for consultants and policymakers who want to make positive changes to the built environment and forecast the effects of those changes.

Before using space syntax as a consultancy tool, there is a need to translate the technical vocabulary currently used in the space syntax community into terms understandable to practitioners and urban planners who have no knowledge of space syntax. In the SSUD project an attempt is made to formulate such a conceptual framework and to use space syntax as a tool to analyse different types of residential neighbourhoods. The objective is that this tool will not only be useful in formulating measures for the (re)vitalization of neighbourhoods, but also for making these measures acceptable to the policymakers and stakeholders who are responsible for the actual implementation.

The utilization of the SSUD model and interaction with practitioners has yielded several insights, which may be useful for future research and consultancy practices. Creating lively, vibrant and safe communities is not always the first priority of the stakeholders involved with the (re)development of neighbourhoods. Traffic safety, political and corporate agendas, and architectural expression are often considered more important than the spatial configuration. It is a serious challenge to deal with these other priorities when convincing the stakeholders of the advantages of spatial interventions.

Especially the current emphasis on traffic safety was a serious issue in three of the eight pilot cases. Municipalities often employ traffic engineers who have the final word in the design of the street pattern. The current traffic safety and road capacity regulations shape the mobility framework of neighbourhoods. The spatial conditions for street vitality and social safety on the one hand and traffic safety on the other are not always the same. Traffic safety is promoted by separating the different mobility networks, by locating the main routes outside the neighbourhood and by limiting the accessibility of residential neighbourhoods. Those measures create mono-functional neighbourhoods and are not favourable for an active street life, vibrant local businesses and natural surveillance.

Building companies and estate developers often want to maximise their profit on a short term. To realize this, they often try to acquire a building plot in which they can implement a single type of dwelling in the whole street or streets. The long-term effects on the neighbourhood itself, such as place quality, variation in building morphology and the relation between building entrances and streets are, however, seldom considered. At present, developers often try to improve the saleability of their projects by creating the image of intimacy. They create a sense of residential privacy and intimacy by turning the homes away from the streets. This design practice results, however, in an inward orientation of homes with no active frontages towards the streets. This generates a low level of human activities in streets and limits the possibilities for natural surveillance. When the street pattern is in addition tree-structured and without active dwelling functions on the ground floor level (e.g. because they are built up with storage boxes and parking garages), an un-necessary complex spatial framework is created that does not support street life and has a negative impact on feelings of safety.

Finally, there is a challenge to overcome the gap between the persons who design the neighbourhoods and the people who inhabit them. Often the designers of housing areas are 'trans-spatial' people. These people work during daytime and have a broad social network in their leisure time not directly bounded to the neighbourhood where they live. The 'spatial dependent' people are the unemployed, the retired and the housewives. They are dependent on what the vicinity of their home offers them in terms of amenities and social activities. A large amount of spatial dependent inhabitants combined with a poor spatial framework for supporting social activities contributes to social unsafe behaviour patterns. Large groups of loitering youngsters, noise disturbances and anti-social behaviour can often be observed in these kinds of neighbourhoods. Therefore, there is a need to gain a spatial understanding on the needs of the spatial dependent people and to communicate that knowledge to urban designers and policymakers.

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Using Satellite Imagery Analysis to Redesign Provincial Parks for a Better Cooling Effect on Cities

The case of South Holland

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Abstract

The purpose of this research is to analyse the thermal behaviour of South Holland provincial parks during heat waves, in order to provide design adaptation guidelines to increase their cooling capacity over the hotspots present in their urban surroundings. This research analyses the thermal behaviour of different land use patches (forests, cropland, grassland, water surfaces, built areas and greenhouse areas) present in the six South Holland provincial parks during heat waves. It studies their average night land surface temperature (LST) (with Modis 11A1), day LST (with Landsat 5TM), NDVI, imperviousness, patch size and patch shape index, and analyses through a multiple regression analysis the impact of each of these last four parameters in the night and day LST for each land use. Within each land use category, NDVI, imperviousness and patch shape index influence differently the thermal behaviour of the patches. NDVI is inversely correlated to day LST for all categories, imperviousness is correlated to day LST for all areas which do not comprise a significant presence of greenhouses (grassland and built patches) and inversely correlated to LST for areas with a high presence of greenhouses (cropland and warehouses). Finally the shape index varies depending on the nature of the surrounding patches, especially for small patches (built areas, forests and greenhouse areas). Most of the hotspots surrounding the Midden-Delfland park are adjacent to grassland patches. The measure to increase the cooling capacity of those patches would consist in a change of land use and or an increase of the NDVI of the existing grassland patches. These suggestions to increase the cooling potential of the parks remain deliberately open in order to allow combining these measures with other spatial planning priorities.

KEYWORDS

urbanism; remote sensing; GIS; urban heat island; cooling effect; climate change adaptation; landscape design

1. INTRODUCTION

1.1 The Urban Heat Island effect

In the Netherlands, a heat wave is defined as a sequence of at least five consecutive summer days (days on which the weather station of De Bilt registers a maximum temperature of 25.0°C or higher), among which there are at least three tropical days (days on which the weather station of De Bilt registers a maximum temperature of 30ºC or more). The European heat wave of the summer of 2003 led to more than 70,000 excess deaths over four months in Central and Western Europe (Brücker, 2005; Robine et al., 2008; Sardon, 2007). More specifically, in the Netherlands, the number of deaths attributed to this event ranged from 1,400 to 2,200 (Garssen et al., 2005). The following European heat wave took place in 2006 and caused in the Netherlands in the month of July alone 1,000 excess deaths (Hoyois et al., 2007) of which 470 in the province of South Holland (Centraal Bureau voor de Statistiek (CBS), 2006). The Dutch province of South Holland was most affected by the 2006 heatwave (CBS, 2006).

During heat waves the urban heat island effect (UHI), which refers to the temperature difference between the built-up areas and their natural surroundings, reaches its peak. The UHI increases daily average temperatures and reduces the capacity to cool off during the night. Urban Heat Islands are caused by changes in the radiative and thermal properties of the environment introduced by human constructions. Recent studies reveal that Dutch cities experience a mean daily UHI effect of 2.3 K and a 95 percentile of 5.3 K during summer (Steeneveld et al., 2011). Moreover, the UHI phenomenon is likely to become a concern in the Netherlands affecting not only larger settlements but also smaller ones (Van Hove et al., 2011). Even though on site air temperature measurements provide a better overview of the intensity of the phenomenon (since it measures directly the temperatures experienced by the population at a particular area) the average night land surface temperature LST is often used as an indicator because for large surfaces it provides a more global overview of the temperature distribution. Because of that reason, most of the previous climatological studies on the cooling potential of parks analyse the LST instead of air temperature (Cao et al. 2010, Choi H. et al. 2012, Cheng X. et al., 2014).

1.2 Greenery as a cooling source

During heat waves cities can benefit from the cooling effect of different greenery typologies existing in and around them. Previous studies on the cooling role of greenery can be divided in two groups: studies dealing with large green infrastructure, and studies concentrating on urban parks.

Green infrastructure

In the first group (studies on large green infrastructure) landscape is considered as an existing natural cooling source. The landscape supports a climate design of the urban environment that promotes cool wind flows within cities. An example of applying air circulation patterns in spatial planning can be found in the Climate Analysis Map for the Stuttgart region, 2008 (City of Stuttgart, 2008; Hebbert & Jankovi, 2010; Hebbert & Webb, 2011; Kazmierczak & Carter, 2010), in the Urban Climate Analysis Map for the Dutch city of Arnhem (developed within the Future Cities project), and in the cool wind corridors of the German city of Freiburg, where the adoption of a Sustainable Urban Development Policy and the Land Use Plan 2020 (Freiburg, 2013). The last plan envisions the transformation of 30 hectares of building space into open areas, not only extend and connect the cities' green infrastructure, but also 'emphasize the cool air flow areas and urban ventilation lines within and outside the city' (Burghardt et al., 2010; City of Freiburg, 2013).

Urban Parks

The second group (studies on the cooling role of greenery) concentrates on urban parks with sizes of up to 500 ha. They analyses the cooling effect these parks have on the surrounding urban environment during calm weather conditions. These studies use several indicators to quantify the cooling capacity of the parks in their surrounding urban areas. Chang et al. (2007) define the local cool island intensity as the temperature difference between the interior of the park and the urban nearby surroundings; Cheng et al. (2014) define the maximum local cool island intensity as the maximum mean land surface temperature of the parks' surroundings and the mean land surface temperature of the parks. Cheng also analyses the maximum cooling range of the parks, which is defined as the maximum distance of maximum local cool island intensity. In principle, the longer the cooling distances the smaller the local cool island intensity. Finally, Cheng also defines the maximum cooling area of the parks, as the largest area influenced by the cooling effect of the park. The local cool island intensity, the maximum cool island intensity, the maximum cooling distance and the maximum cooling area of parks are different indicators of the parks cooling effect; however, they are all interrelated.

The main factors influencing the local cool island intensity under calm weather conditions are the size of the parks (Von Stülpnagel et al., 1990; Upmanis et al., 1998; Cheng et al, 2014), the height and structure of the surrounding constructions (Upmanis et al., 1998; Jauregui, 1975, 1990-1991; Spronken-Smith, 1994), and the design of the parks. Regarding the design of the parks, previous studies concluded that the role of vegetation in parks differs, depending on whether it is day or night. During the day, local cool island intensity is related to the area of trees and shrubs inside the park (Cao et al., 2010; Potchter et al., 2006; Yu & Hien, 2006; Zhou et al., 2011), while at night the coolest parks are those without trees (Chang et al., 2007; Taha, 1991). Thus, grassland presents higher diurnal surface temperatures than tree areas while at night the surface temperature of grassland drops further compared to the wooded areas, especially when grassland is irrigated (Spronken-Smith & Oke, 2000). A strong correlation was also found between paved surfaces and LST (Zhou et al., 2011; Li et al., 2011); more specifically, diurnal LST is correlated with the largest patch index of the urban land-use type (Cheng et al., 2014). The same impervious surface produces a smaller UHI effect when it is spatially distributed (Li et al., 2011).

Finally, the role of water surfaces is unclear, but appears to depend on the size and depth of the body of water. Some studies revealed water had a positive effect on local cool island intensity (Saaroni & Ziv, 2003), while others have suggested its contribution is negligible (Cao et al., 2010).

South Holland provincial parks

This research falls somewhere between these two groups. On the one hand the South Holland provincial parks analysed (Midden-Delfland, Duin Horst en Weide, Wijk en Wouden, Bentwoud/Rottemeren, Hollands Plassengebied and IJsselmonde) are large enough to be considered as part of the landscape (Figure 1) and on the other hand these are man-made parks that were completely designed. All trees were planted and most water elements were dug out. The provincial main strategic guidelines aim at creating a province that is resilient to climate change and that is characterised by its spatial and sustainable quality however its spatial vision (Structuurvisie Zuid-Holland, 2010) doesn´t specifically address the UHI phenomenon. Furthermore, with 1227 inhabitants per km2 the province of South Holland is the densest province in The Netherlands and the one most affected by the UHI effect (Centraal Bureau voor de Statistiek, 2006).

1.3 Research questions

In order to allow urban areas to benefit from the cooling capacity that provincial parks may offer, we need a better understanding of the thermal behaviour of regional parks and their spatial components.

The main research question underlying this paper is:

- How can the development of the regional park system in the province of South Holland be optimised in order to provide surrounding urban areas with a long-term source of natural cooling capacity?

In order to answer this question we have formulated several sub-questions:

- What is the thermal behaviour of the different land-use categories (forests, cropland, grassland, water surfaces, built areas and greenhouse areas) that can be found in South Holland provincial parks? How do the normalized difference vegetation index (NDVI), imperviousness coefficient, patch size and patch shape index affect their average night-time LST and their average day-time LST during heat waves?

- How can we design adaptation guidelines to increase the cooling capacity of provincial parks? Can we use remote sensing to diagnose heat accumulation in urban areas surrounding parks and to prescribe measures to increase the cooling capacity of the adjacent park areas?

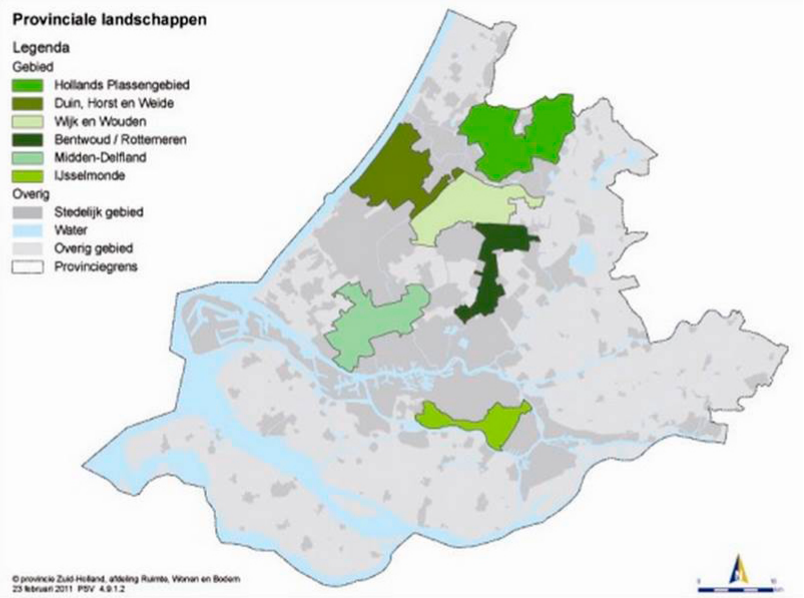


Figure 1: South Holland provincial parks (Province of South Holland, Spatial Planning and Housing Department, 2011)

2. METHODOLOGY

2.1 Definition of thermal behaviour of land-use categories in South Holland provincial parks

The six main land-use categories defined in the Spatial Vision of the region of South Holland, and which can be identified in its six provincial parks are: forests, cropland, grassland, water surfaces, built areas and greenhouse areas. For each of these categories we have used as indicators of thermal behaviour the average night-time land surface temperature (LST) and the average day-time LST, and as influencing parameters: NDVI, imperviousness coefficient, size of the land-use patch and shape index of the surface patch. For each patch in each land-use category we have calculated the average values of the above mentioned parameters, and we have carried out a multiple regression analysis in order to understand what parameters influence most the thermal behaviour of the patches of each land-use category. We have used remote satellite imagery to map and calculate night LST, day LST and NDVI. All satellite images have been obtained through the US Geological Survey (USGS) webpage, Earth Resources Observation and Science Center (EROS).

Mapping thermal behaviour indicators: Night and day LST

We have used nine Modis 11A1 satellite images (from the 15th till the 20th of July), retrieved during the second heat wave of 2006 to map and calculate average night-time LST. Modis 11A1 is a Modis product which bands provide LST and emissivity values on a daily basis with a 1 km resolution. For the calculation of the day LST we have used Landsat 5 TM satellite imagery (retrieved on the 16th of July). Landsat 5 has a 16-day repeat cycle referenced to the Worldwide Reference System 2. Its data files, which consist of seven spectral bands, were downloaded from the US Geological Survey (USGS), EROS Center webpage. We calculated and mapped the diurnal LST using ENVI 4.7 software and following the Yale Center for Earth Observation 2010 instructions to convert thermal infrared band 6 into temperatures. Landsat TM collects band 6 at a resolution of 120 m and further resamples it to 30 meters. We first made a geometrical correction and calibrated band 6. The atmospherically corrected radiance was then obtained by applying Coll's equation (Coll et al., 2010):

$$CVR2 = [(CVR1 - L)/] - [(1-)*(L)/] \qquad \text{(Equation 1)}$$

Where:

- CVR2 is the atmospherically corrected cell value as radiance
- CVR1 is the cell value as radiance
- L is upwelling radiance
- L is downwelling radiance
- is transmittance
- is emissivity (typically 0.95)

The transmittance and the upwelling, as well as the downwelling radiance, were retrieved from NASA's webpage. Finally, the radiance was transformed into temperatures (Kelvin and Celsius) (Figure 2).

$$T = K2 / [\ln((K1/CVR2) + 1)] \qquad \text{(Equation 2)}$$

Where:

- T is degrees Kelvin
- CVR2 is the atmospherically corrected cell value as radiance

The result of the processed Landsat 5 TM imagery is shown in Figure 2.

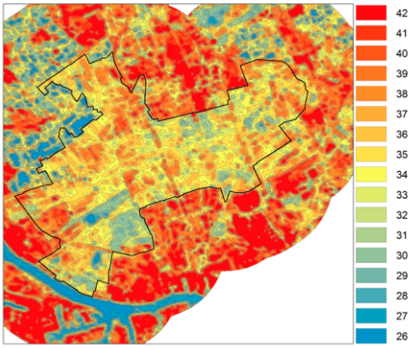


Figure 2: Land surface temperature image retrieved from Landsat 5TM

Mapping influencing parameters: NDVI, imperviousness, patch size and shape

We have used Landsat 5TM imagery retrieved during the heat wave of 2006 to map and (on the 16th of July) to calculate the average NDVI. We have used ATCOR 2.3 to correct geometrically and atmospherically the raw satellite imagery. The index is defined as (NIR-VIS)/(NIR+VIS), where VIS (visible radiation obtained in band 3) is the surface reflectance in the red region (650 nm) and NIR (near-infrared radiation obtained in band 4) is the surface reflectance in the near-infrared region (850 nm)

We have used TOP 10 NL GIS file to calculate the impervious surface area within the parks, considering the areas covered by buildings and roads as 100% impervious surfaces and the rest of the surfaces as 0% impervious surfaces.

In order to estimate the influence of the patch shape on the thermal behaviour of the patches per land-use category, we have used the landscape shape index (LSI) defined by Patton (1975) and that calculates the compactness degree (Cao et al., 2010):

$$LSI = Pt/(2\sqrt{(\pi . A)}) \qquad \text{(Equation 3)}$$

Where Pt is the perimeter of the patch and A is the area of the patch.

Overall, we analysed the thermal indicators (night and day LST) and the influencing parameters (NDVI, imperviousness and size and shape index) of 32 forest patches, 68 cropland patches, 115 grassland patches, 28 water surfaces, and 2284 urban areas and 339 greenhouse areas.

Surface thermal classification of South Holland provincial parks

Even though NDVI and imperviousness of the patches have different influences on night and day LST depending on the analysed land use, the average values of these parameters are often similar. In order to obtain a better understanding of the thermal behaviour of the different land-use patches, we have carried out in GIS an unsupervised classification of the overlap of the day LST, NDVI and imperviousness maps, and we have obtained five thermal clusters in the South Holland provincial parks. We have further calculated the proportion of each of these thermal clusters for each of the studied land uses.

2.2 Definition of design adaptation guidelines to increase the cooling capacity of Midden-Delfland provincial park

In this section we have studied how we could use remote sensing to diagnose heat accumulation in urban areas surrounding parks and how we could prescribe measures to increase the cooling capacity of the adjacent park areas.

Heat diagnosis: heat accumulation in urban areas surrounding parks

As revealed by the climatologic studies previously discussed, the design of parks influences their cooling capacity. One of the indicators used to evaluate a park's cooling capacity is the local cool island intensity, which measures the temperature difference of the park's immediate surroundings and the temperature inside the park. For large parks such as the South Holland provincial parks, which sizes range from 3,745 to 10,658 ha it is complicated to define the local cool island intensity, since the temperatures within the parks vary greatly and the same occurs with the areas surrounding the parks. The local cool island intensity varies consistently, depending on which area of the park is selected, and which area surrounding the park is picked. Therefore for this study we have chosen to analyse the temperature differences between the urban hotspots surrounding one of the parks, and the park areas adjacent to those hotspots and closer than 500 m. We have chosen Midden-Delfland park, which is the South Holland provincial park located between the region of The Hague and Rotterdam.

We have defined two types of hotspots within a distance of 500 m from the parks boundary. The first category comprises areas with an LST above 42°C and areas greater than 10 ha. The second hotspot group comprises areas with an LST above 36°C and with lengths connecting the park larger than 1500 m.

Tool: We have used day LST maps obtained through Landsat 5TM processing to map the hotspots in the urban areas surrounding the park. We have chosen to map only day LST hotspot, due to the higher resolution of Landsat 5TM imagery (120m) compared to Modis 11A1 (1km). Landsat 5TM seems more appropriate for urban analysis (Figure 2).

Identifying park areas adjacent to hotspots with an improvable cooling capacity

We further analysed the park areas adjacent to the hotspots and we identified the areas that had LST differences of less than 10°C compared with the hotspots. We call those areas "park adaptation areas" (PAA). These are the areas for which we suggest to modify the park design in order to increase the temperature difference with the hotspots, and thus to increase the local cool island intensity corresponding to those hotspots.

Tool: We imported and combined LST images into Arcmap 10 to calculate the temperature difference between the different pixels throughout the LST map (Figure 3).

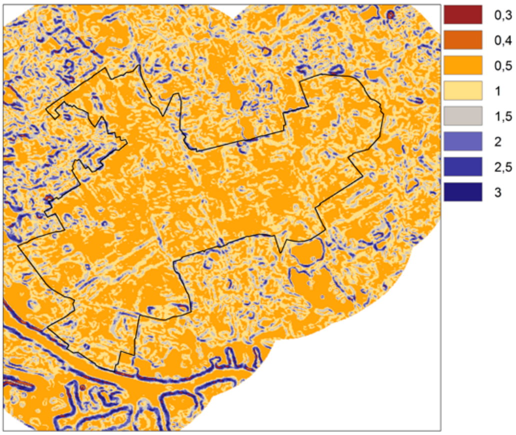


Figure 3: Land surface temperature differences in Midden-Delfland

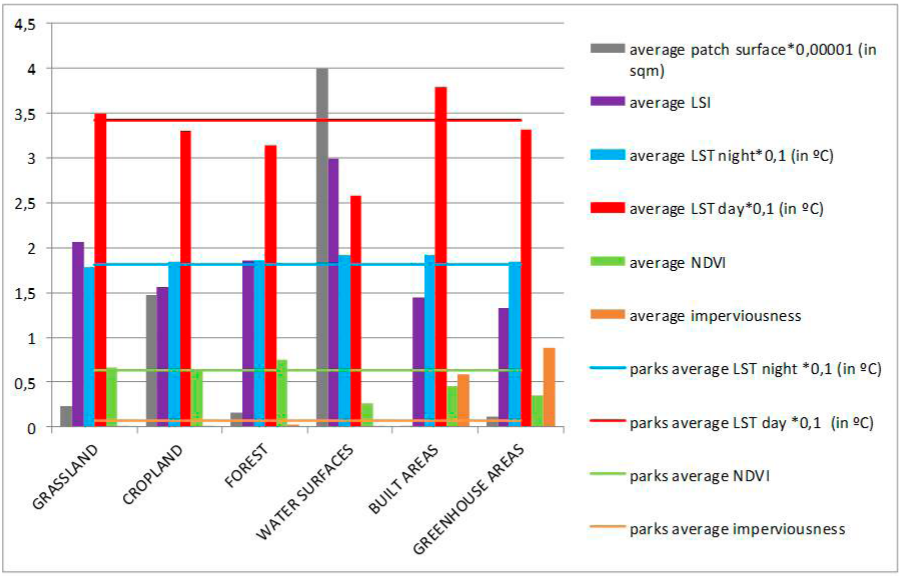
Prescribing measures to increase the cooling capacity of the park areas adjacent to hotspots

We have used the results obtained in section 1 to define adaptation measures in order to increase the cooling capacity of the PAAs. The measures consist, either in a change of land use, or on the increase of NDVI, decrease of imperviousness or on changing the size and/or shape index of the patches currently occupying the PAAs.

3. RESULTS

3.1 Results of the analysis of night LST, day LST, NDVI, imperviousness, patch surface and patch shape index for six main land-use categories in South Holland provincial parks

The analysis of the average night LST reveals that the values presented for each land use only vary in 1,4ºC. Maximum night LST is 19,2ºC registered in built areas and water surfaces and minimum night LST is 17,8ºC registered in grassland surfaces. In turn, the average day LST presents differences of up to 12ºC with an average day LST of 25,8ºC for water surfaces and 37,9ºC for built areas. Forest patches present the second lowest day LST with 31,4ºC. Greenhouse patches and cropland present an average LST 1,8ºC lower than grassland. Greenhouses are characterized by highly reflective glass roofs, which help reduce the surface temperatures. The difference between cropland and grassland is mainly due to the irrigation of cropland (Graph 1).



Graph 1: Average night LST, day LST, NDVI, imperviousness, patch surface and patch shape index for the six main land-use typologies of South Holland provincial parks.

Forests

As concluded by previous scholars, surfaces of trees contribute to increasing the diurnal cooling capacity of parks (Cao et al., 2010; Potchter et al., 2006; Yu et al., 2006; Zhou et al., 2011). Indeed, the average day LST of forested areas is 2,7ºC below the park's average, whereas the forested areas night LST is slightly above the parks average (Graph 1). The multiple regression analysis of the average day LST, NDVI, imperviousness, size and shape index of 16 forest patches with surfaces of more than 1 ha of South Holland provincial parks (Graph 2) reveals that a multiple correlation coefficient of R = 0,8 and R2 = 0,6 relating day LST to the rest of parameters for forest patches, with the following coefficients:

LST d = 76,4 – 59,5*NDVI + 0,1*I + 1,5E-05*S -0,2*LSI, where LST d is the day LST, I is the imperviousness coefficient, S is the surface of the patch and LSI is the patch shape index. (Graph 2).

NDVI and LSI play the most important role for the determination of day LST. The inverse correlation between day-time LST and NDVI (which range from 0,7 to 0,8, Graph 2) is aligned with previous research, in turn, the inverse correlation between day LST and the slenderness of the patches is surprising. A more detailed analysis of the size and shape of the forest patches reveals that these are relatively small and the larger patches contain numerous narrowings. South Holland provincial parks include a total of 7,774 forest patches, of which only 585 patches (7,5 percent) have surfaces of more than 10 ha. GIS is only able to calculate the average day LST of 2,7 percent of these 585 patches, due to the amount of bottlenecks which prevent the program from calculating with Landsat the average patch LST (Landsat 5TM band 6, which is the one used for the day LST calculation, has a resolution of 120 m, which has been further resampled into 30 m; this resolution does not allow to calculate LST values of the finer narrowings). The analysed patches (Graph 2), present an average patch surface of 1,6 ha, and an average patch LSI of 1,9. They are the ones presenting shapes regular enough to allow GIS to extract the average LST, however, some of the analysed patches present widths below 100 m. Therefore, the inverse correlation found between the day LST and the slenderness of the shape might be the result of the influence of the surroundings of the analysed patches (Figure 4), which might increase or decrease the average temperature of the forest patch depending on its land use.

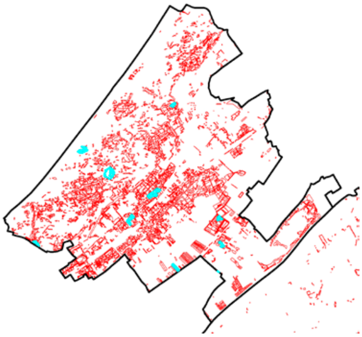
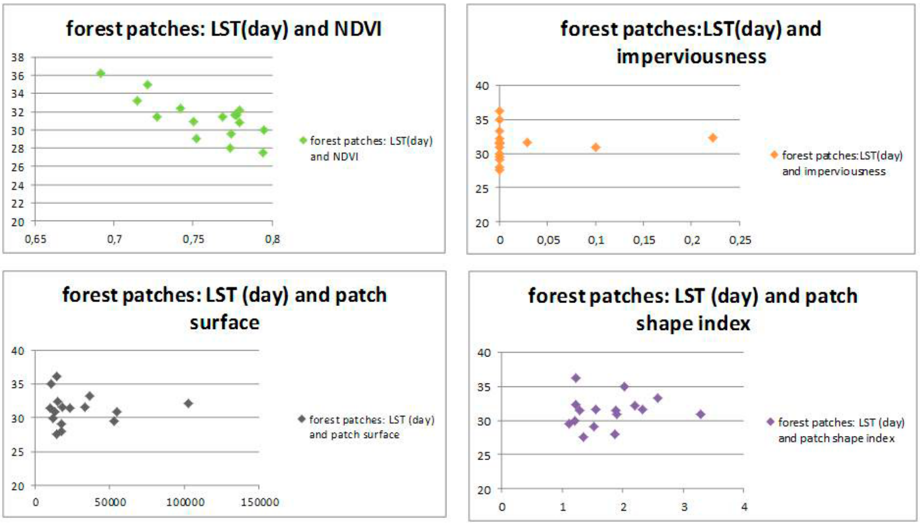


Figure 4: In red, forest patches of Duin, Horst en Weide provincial park, with small surfaces and numerous narrowings. In blue, analysed forest patches.



Graph 2: Analysis of the relationship between the different parameters and day-time LST for forest patches with surfaces above 1 ha in South Holland provincial parks.

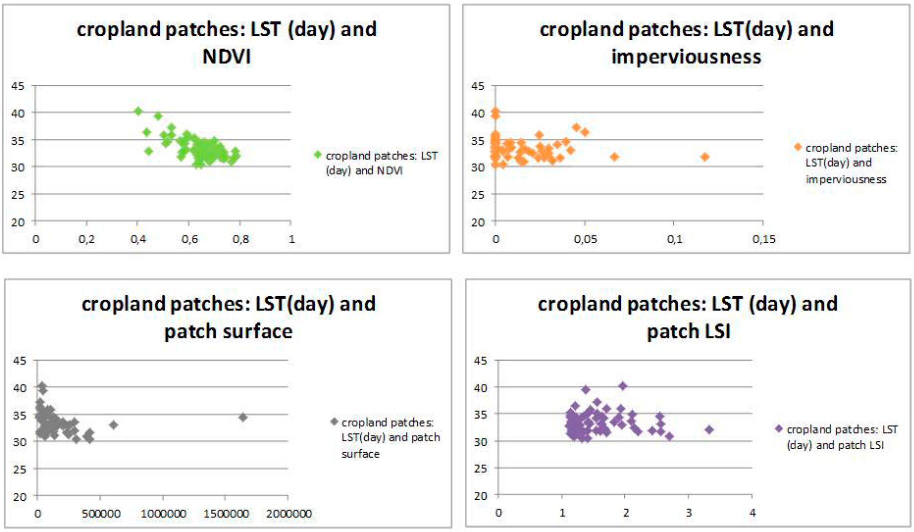
Cropland

Cropland average day LST is approximately 1°C below the average park day LST (graph 1). The multiple regression analysis of the average day LST, NDVI, imperviousness, size and shape index of 68 analysed cropland patches of South Holland provincial parks reveals that a multiple correlation coefficient of R = 0,7 and R2 = 0,5 relating day LST to the rest of parameters for cropland patches, with the following coefficients:

LST d = 42,8 – 15,2*NDVI −18,8*I – 1,4E-06*S + 0,5*LSI, where LST d is the day LST, I is the imperviousness coefficient, S is the surface of the patch and LSI is the patch shape index.

Imperviousness and NDVI play the most important role for the determination of day LST. As discussed earlier the inverse correlation between day LST and NDVI seems predictable. In turn, imperviousness is typically correlated with day LST, whereas in this case we find an inverse correlation. If we analyse the imperviousness of the cropland patches, we can see that most of the impervious surface is covered by greenhouses, and that, as described in 3.1., due to the reflectance of the glass, the average day LST of greenhouses is 1°C lower than the park average surface temperature and presents a similar average LST as the cropland patches, thus contributing to the cooling potential of the patches.

The regression analysis also reveals that day LST is correlated to the slenderness of the patches. The average size of the analysed patches is 14,7 ha, and the average LSI of the analysed patches is 1,5. The more compact the cropland patch, the cooler its surface (Graph 3).



Graph 3: Analysis of the relationship between the different parameters and day-time LST for cropland patches in South Holland provincial parks.

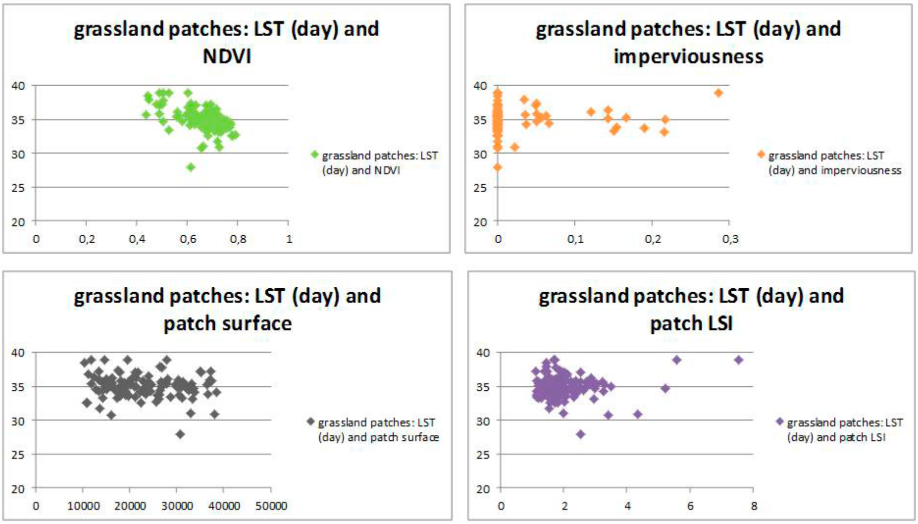
Grassland

Grassland is the land use with the worst thermal behaviour present in South Holland parks, and it actually presents an average day LST 0,7°C higher than the parks average (Graph 1). The multiple regression analysis (Graph 4) of the average day LST, NDVI, imperviousness, size and shape index of 189 grassland patches with surfaces above 1 ha of South Holland provincial parks reveals that a multiple correlation coefficient of R = 0,5 and R2 = 0,3 relating day LST to the rest of parameters for grassland patches, with the following coefficients:

LST d = 42,7 – 10,9*NDVI + 0,5*I - 2,3E-05*S + 0,02*LSI, where LST d is the day LST, I is the imperviousness coefficient, S is the surface of the patch and LSI is the patch shape index.

Even though the multiple correlation analysis presents a pretty weak correlation (R2 = 0,3), we observe that NDVI and imperviousness play the most important role for the determination of day LST. Compared to the cropland patch analysis, the imperviousness is correlated to the day LST in the case of the grassland patches. This is due to the fact that most of the impervious surfaces comprise conventional roof and pavement surface materials (instead of glass roofs, which are found in the cropland patches).

Since the main difference between cropland and grassland is their irrigation pattern, it seems that in this case evapotranspiration is generating the surface temperature difference between these two land uses. Sproncken-Smith (2000) already highlighted the importance of irrigation to increase the cooling effect of parks.



Graph 4: Analysis of the relationship between the different parameters and day-time LST for grassland patches in South Holland provincial parks.

Water surfaces

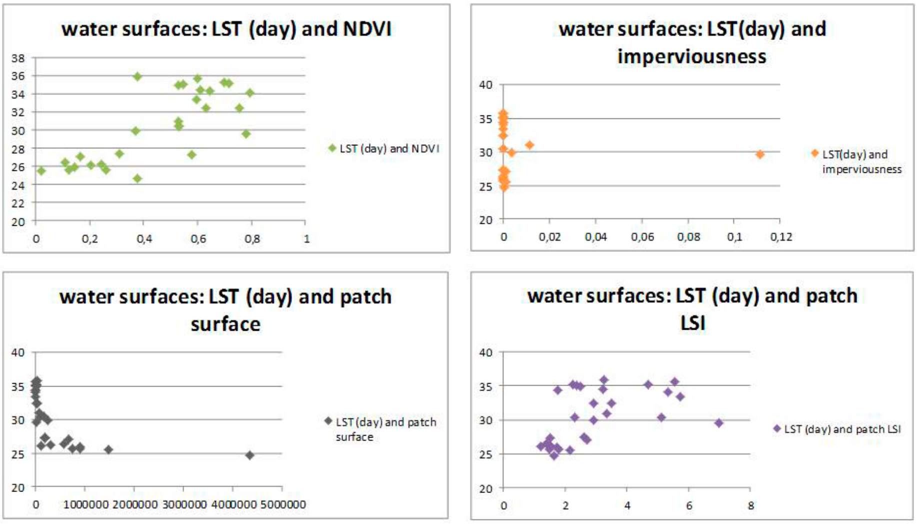
The cooling effect of water surfaces is unclear and seems to vary from case to case (Saaroni and Ziv, 2003; Cao et al., 2010). In the summer of 2006, in the South Holland provincial parks, water surfaces seem to present the lowest average LST with 25,8ºC (Graph1). The sizes of the patches present great variations, and have surfaces that range from 600 sqm till 433 ha. Overall the average patch surface is the highest, with 40 ha, and the average LSI is also the highest, with a value of 3. Small surfaces with high shape indexes correspond to canals, whereas large compact water surfaces correspond to water ponds.

The multiple regression analysis of the average day LST, NDVI, imperviousness and size and shape index of 28 analysed water surface patches of South Holland provincial parks (graph 5) that a multiple correlation coefficient of R = 0,8 and R2 = 0,6 relating day LST to the rest of parameters for water surface patches, with the following coefficients:

$LST\ d = 26 + 10{,}7*NDVI - 1{,}4E{-}06*S + 0{,}02*LSI$, where LST d is the day LST, S is the surface of the patch and LSI is the patch shape index.

NDVI plays the most important role for the determination of day LST, and it increases the water surface temperature. During the summer, in the Netherlands, the water surfaces get covered with lily pads and other water surface vegetation, which have a negative contribution on the water surface cooling capacity.

It seems there is a slight positive correlation between the slenderness of the patch and the day LST.



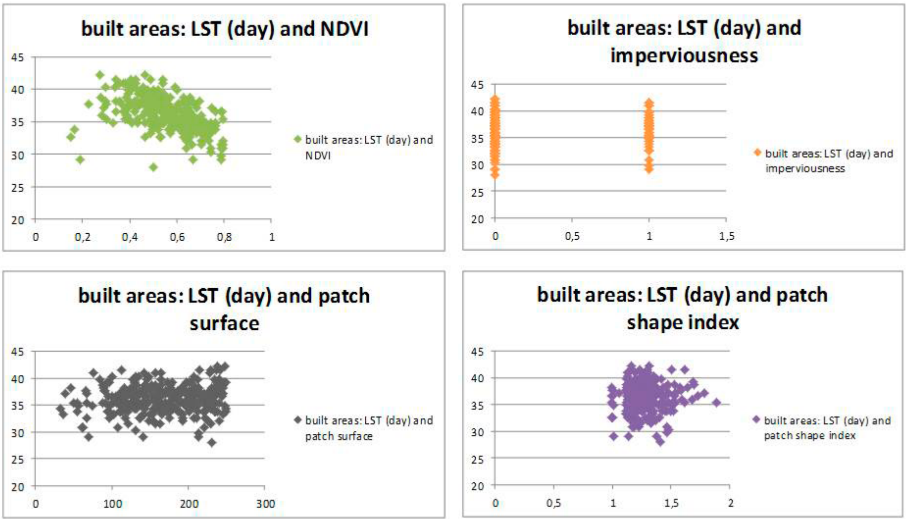
Graph 5: Analysis of the relationship between the different parameters and day-time LST for water surfaces in South Holland provincial parks.

Building patches

Built areas are the land use presenting the highest day LST of South Holland provincial parks with an average day LST of 37,9°C, 3,7°C higher than the average park day LST. Previous studies concluded that the size of urban patches and the amount of paved surfaces is normally correlated with the increase of LST (Cheng et al., 2014; Zhou et al., 2011; Li et al., 2011). However, the structure of the built patches of South Holland parks is one of small and scattered patches. The average built-up patch size is 970 sqm and the average LSI is 1,4, which hinders the analysis with the use of Landsat imagery. As a matter of fact, the multiple regression analysis of the average day LST, NDVI, imperviousness, size and shape index of 323 built patches with surfaces below 250 m2 of South Holland provincial parks (Graph 6) reveals that only a weak multiple correlation coefficient of R = 0,5 and R2 = 0,2 relates day LST to the rest of the parameters, with the following coefficients:

$LST\ d = 39{,}7 - 9{,}1*NDVI - 0{,}02*I + 4{,}2E\text{-}03*S + 0{,}6*LSI$, where LST d is the day LST, I is the imperviousness coefficient, S is the surface of the patch and LSI is the patch shape index.

In this case, NDVI and LSI play the most important role for the determination of day LST. Most of these patches are surrounded by other urban patches, thus the more slender the patch, the more influenced by the surrounding urban environment. The use of Landsat imagery for the assessment of small land-use patches can thus be misleading due to the lack of resolution of the satellite imagery.



Graph 6: Analysis of the relationship between the different parameters and day-time LST for built patches with surfaces below 250 m2 in South Holland provincial parks.

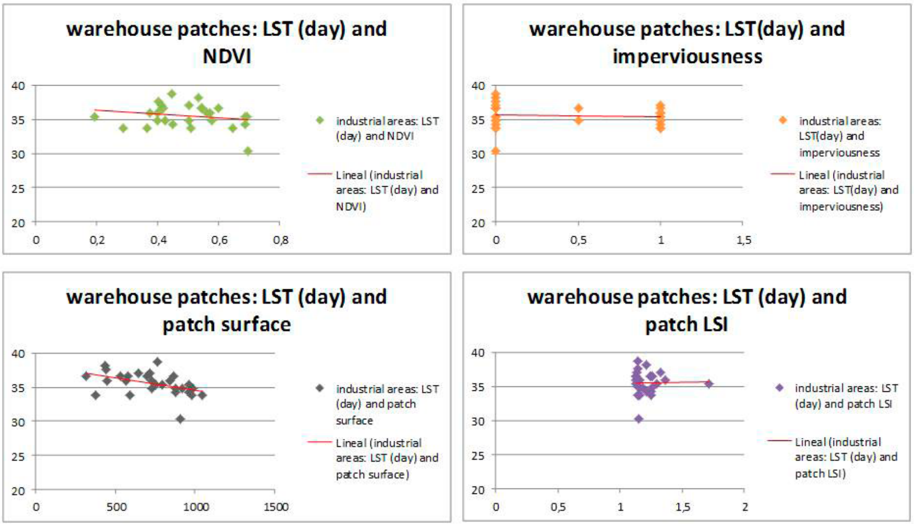
Greenhouse patches

Warehouse patches present an average day LST of 33,1°C, which is 1°C lower than the average South Holland park LSTs (Graph 1). Thus they have a cooling effect. Most of the warehouses present in South Holland provincial parks are actually greenhouses with highly reflective glass roofs, which is what contributes to the reduction of the surface temperature of these patches.

The multiple regression analysis of the average day LST, NDVI, imperviousness, size and shape index of 28 industrial patches with surfaces below 1,000 m2 of South Holland provincial parks (Graph 7) reveals that a multiple correlation coefficient of R = 0,5 and R2 = 0,3 relating day LST to the rest of parameters, with the following coefficients:

$\text{LST d} = 39{,}8 - 4{,}1*\text{NDVI} - 0{,}6*\text{I} - 3{,}7\text{E-}03*\text{S} + 0{,}6*\text{LSI}$, where LST d is the day LST, I is the imperviousness coefficient, S is the surface of the patch and LSI is the patch shape index.

NDVI, imperviousness and LSI play the most important role for the determination of day LST. We have found an inverse correlation between day LST and imperviousness due to the fact that even though greenhouse areas represent surfaces with high imperviousness, they contribute to the reduction of the surface temperature due to the high reflectance of their glass roofs. We have also noted that day LST is slightly correlated to the slenderness of the patches, due to the influence of warmer surroundings.



Graph 7: Analysis of the relationship between the different parameters and day-time LST for warehouse patches with surfaces below 1,000 sqm in South Holland provincial parks.

Conclusion

The analysis of all the land-use patches shows that the LST of the different park components varies depending on their land use. The multiple correlation analysis of the patch night LST and day LST for each land use reveals that NDVI is inversely correlated to LST (in both cases) for all studied land uses (forest, cropland, grassland, water surface, built areas and warehouse areas). In turn, imperviousness and the shape of patches vary differently depending on the land use, and the size of the patches.

As far as imperviousness is concerned, generally imperviousness is correlated to the day LST, except for cropland and greenhouse areas, where the impervious surfaces represent greenhouse surfaces, which have highly reflective roofs which contribute to the reduction of day LST.

The conclusions regarding the influence of the patch shape in the average LST are highly influenced by the nature of the areas surrounding the studied patches. In that sense we can organize the studied land uses in three groups. The first group is made of large patches surrounded with warmer areas: it is the case of cropland, grassland and water surfaces. The second group is made of small patches clustered around each other: this is the case of forest patches and built area patches. The third group is formed by small-scattered patches, surrounded by warmer areas: this is the case of the warehouse patches. The first land-use group (cropland, grassland and water surfaces) sees its average LST increase with the increase of the slenderness of its patches. The more slender, the more influenced by their warmer surroundings. The second group (forest and built areas) is influenced by the average LST of their own patches. The more slender the forest patch, the cooler the temperature due to the presence of the surrounding forests. The more slender the built area, the more influenced it will be by the high LST of the surrounding built areas. The third group of greenhouses, is surrounded by warm areas, the more slender the patches, the higher the day LST.

Surface thermal classification

The unsupervised thermal classification of the day LST, NDVI and imperviousness layers reveals that there are five surface clusters in South Holland provincial parks, each of these clusters have different average day LST, NDVI and imperviousness combinations. The average night LST doesn´t vary much between the different clusters, in turn, day LST varies considerably, and presents the lowest average values for cluster 1 and the highest values for cluster 5 (graph 8). The analysis of the cluster composition of the different land-use categories (graph 9) reveals that cluster 1 can be assimilated to water surfaces, cluster 2 to trees and bush areas, cluster 3 could be assimilated with greener grassland patches, whereas cluster 4 covers warmer grassland patches, and finally cluster 5 can be identified with urban areas and bare soil zones (Figure 6).

Since the greenhouse patches only represent a very small part of the parks surface the unsupervised classification hasn´t produced a specific cluster assimilable to glass surfaces. In turn, greenhouse surfaces fall sometimes into the cluster 1 category (assimilated with water), and other times into cluster 2 category (assimilated with trees and bush areas) (Figure 5).

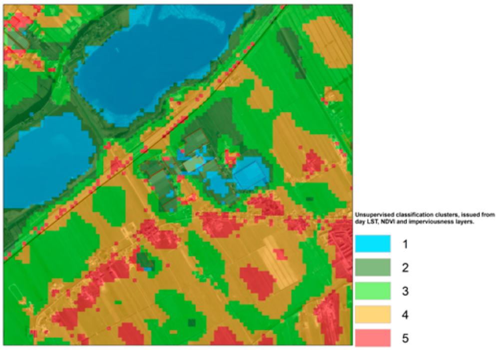


Figure 5: Unsupervised classification clusters from day LST, NDVI and imperviousness. The greenhouse areas are classified either in the same cluster as water or on the same cluster of forested areas. Due to their small presence in the parks, they are grouped with categories with similar thermal behaviour.

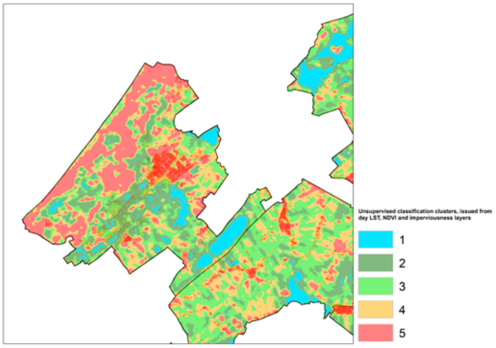
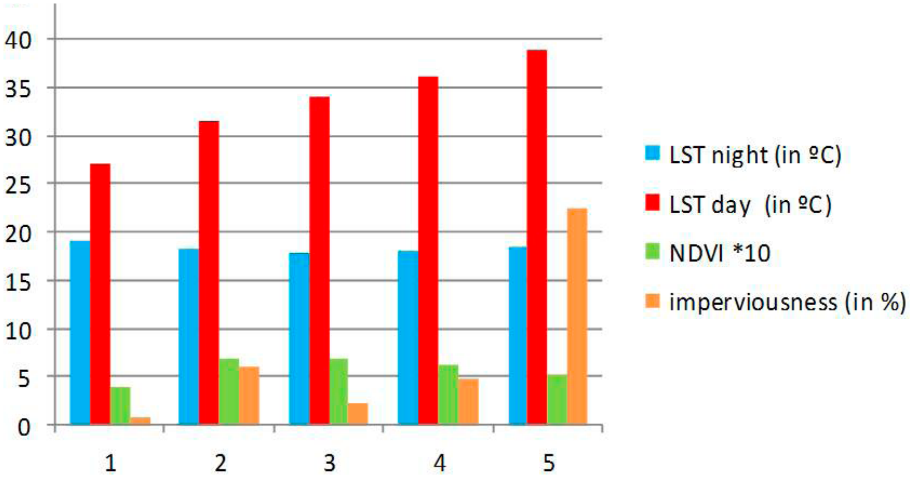
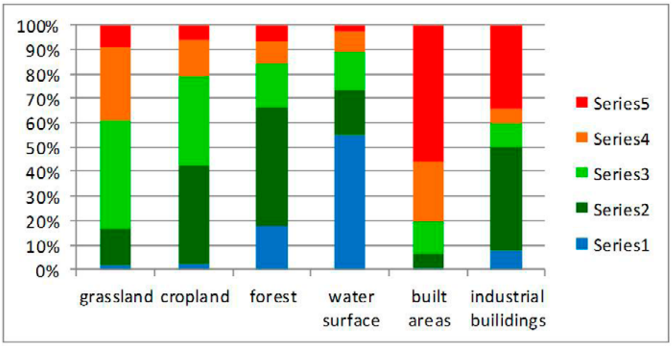


Figure 6: Unsupervised classification clusters from day LST, NDVI and imperviousness. The bare soil areas of the coast are classified in the same cluster as the built up areas. They have a similar thermal behaviour.



Graph 8: Average day LST, night LST, NDVI and imperviousness for the five different clusters produced by the unsupervised classification of the day LST, NDVI and imperviousness maps.



Graph 9: Cluster composition of the different land use present in South Holland provincial parks.

3.2 Defining adaptation measures to improve provincial parks cooling capacity

Once we have analysed the thermal behaviour of the different land-use typologies encountered in South Holland provincial parks, we have identified park adaptation areas (PAA) which are park areas adjacent to urban hotspots surrounding the parks, and which could potentially help cool these hotspots.

Identifying hotspots in the urban areas surrounding the parks

Hotspots with LST above 41°C

The analysis of the hotspots surrounding the Midden-Delfland park reveals that there are 8 major hotspots with an LST above 41°C and with an average size of 86 ha within a distance of 500 m from the park's boundary. All of them correspond with industrial areas (Figure 7). They are scattered around the park's perimeter and the length of the hotspots (hotspot's sides connecting to the park) ranges from 450 m (corresponding to hotspot 1) to 1,000 m (corresponding to hotspot 4) (Figure 7).

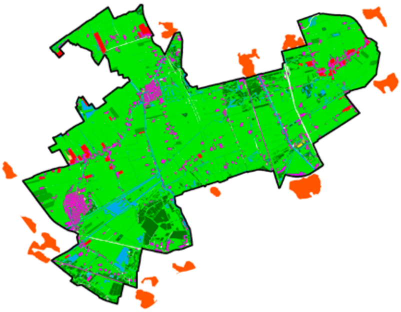


Figure 7: Midden-Delfland hotspots with and LST>41°C surrounding the park.

Hotspots with an LST between 36ºC and 41ºC

The analysis of the hotspots surrounding the Midden-Delfland park reveals that there are 3 major hotspots with an LST ranging from 36ºC till 41ºC and with a connecting length with the park longer than 1500 m (Figure 8). These hotspots have areas that range from 300 to 600 ha, and their dominant land use is residential. The PAA has areas that range from 100 to 600 ha for each hotspot. In this case the dominant land use in the hotspots is residential.

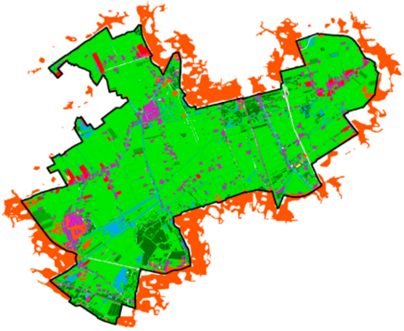


Figure 8. Midden-Delfland hotspots with 41ºC>LST>36ºC surrounding the park.

Prescribing measures to improve the cooling capacity of the park areas adjacent to the urban hotspots

Once the hotspots have been identified, we have prepared a chart to analyse the park adaptation areas (PAA) and the measures that could help increase the cooling capacity of the PAA, thus reducing the intensity of the hotspots (Figures 9 and 10). For each identified hotspot we have calculated the day LST difference between the hotspot and the PAA. The measures to redesign the PAA´s which have a LST difference below 10ºC with the hotspots (for hotspots above 41ºC: hotspots 2, 3, 4, 5 and 8; and for hotspots with LST´s between 36ºC and 41ºC: hotspots 1, 2 and 3) primarily consist in a change of land use. The dominant land use of the before-mentioned PAA´s is grassland, which is the land use with the second worst thermal behaviour encountered in South Holland provincial parks (Graph 1), after the built up patches. The conversion of those patches into cropland (reduction of up to 1,8ºC), forest (reduction of up to 4ºC), water surfaces (reduction of up to 8ºC) of greenhouse areas (reduction of up to 1,7ºC) would increase their cooling capacity. Further, in case the grassland land use is to be maintained, an increase of the existing patches NDVI (through the increase of irrigation or introduction of particular vegetation species) would also contribute to the increase of the cooling capacity of those PAAs. A reduction of those grassland patches’ imperviousness would also theoretically contribute to a decrease of their average LST, however, the analysis reveals that the analysed PAAs seem to present pretty low imperviousness values already. Overall, there are several options to increase the cooling capacity of the PAAs, which allows combining the thermal considerations with other spatial planning priorities.

Hotspots number 1, 6 and 7 with LST above 41°C, present LST differences with their corresponding PAA´s greater than 12°C. Those patches are primarily occupied by forested areas. The adaptation measures to be introduced would consist in increasing the advection between hotspot and park (through the creation of cool wind corridors, reduction of the height of buildings surrounding the parks…) rather than modifying the land use of the park adjacent area, since forests already present the second lowest surface temperature after water surfaces.

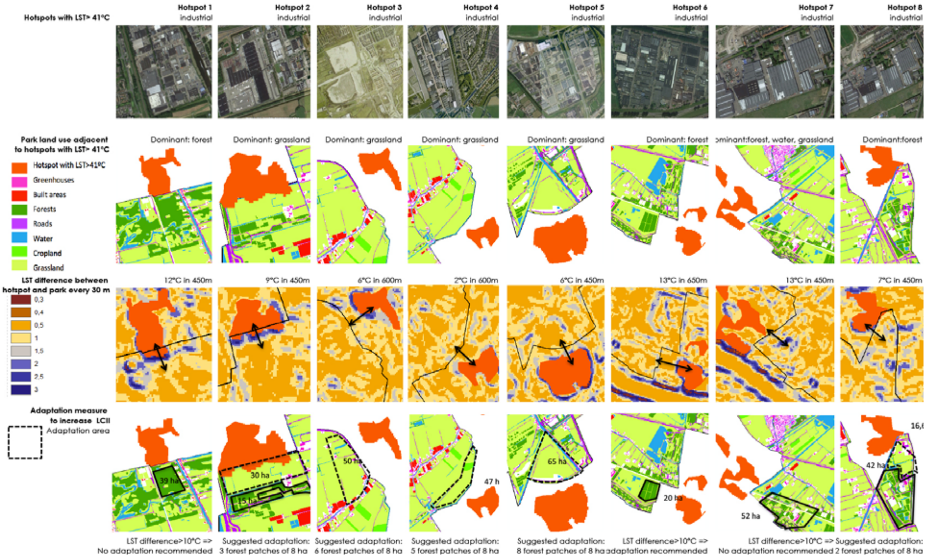


Figure 9. Diagnosis and adaptation design for hotspots with an LST>41°C.

4. CONCLUSIONS

The average LST of South Holland provincial parks varies depending on the land use. The average LST increases from 25,9°C for water surfaces, to 31,4°C for forests, 33°C for cropland, 33,1°C for greenhouse areas, 34,9°C for grassland patches and 37,9°C for built areas. Within each land-use category, NDVI, imperviousness and patch shape index influence differently their thermal behaviour of the patches. NDVI is inversely correlated to day LST for all categories, imperviousness is correlated to day LST for all areas which do not comprise a significant presence of greenhouses (grassland and built patches) and inversely correlated to LST for areas with a high presence of greenhouses (cropland and warehouses). Finally LSI varies depending on the nature of the surrounding patches, especially for small patches (built areas, forests and greenhouse areas).

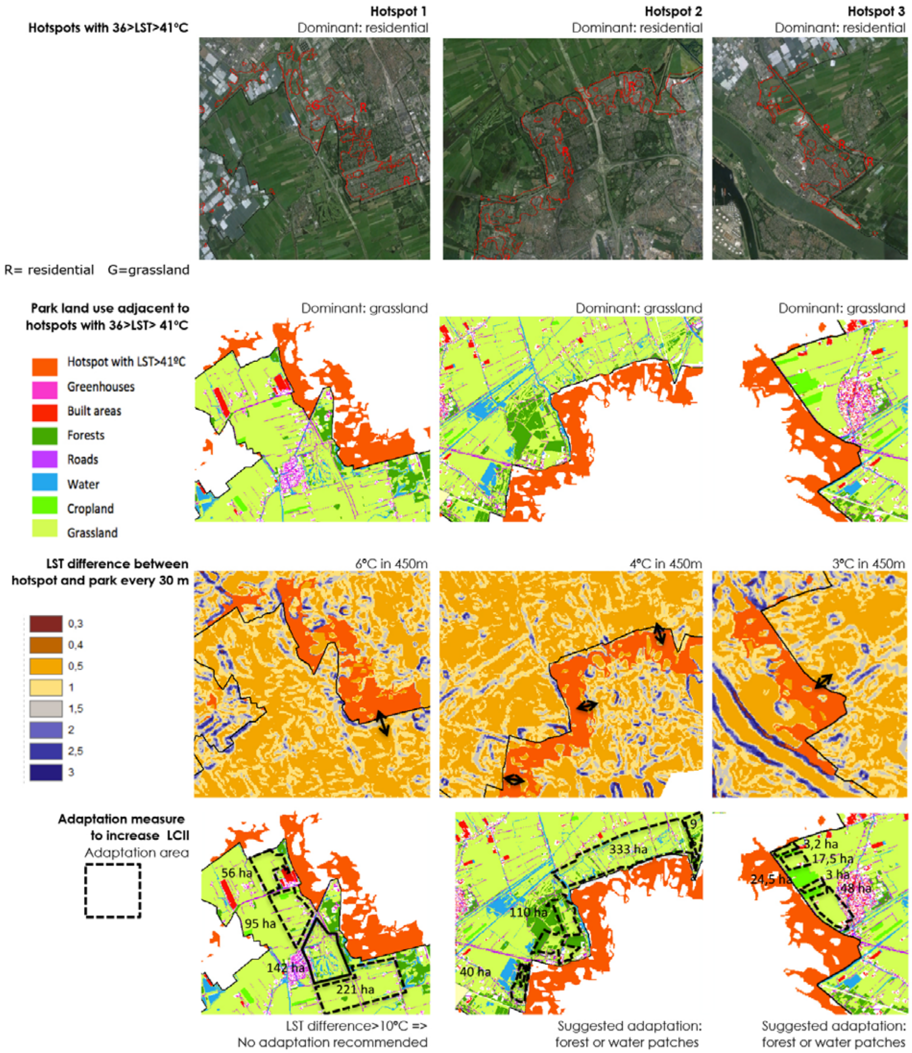


Figure 10. Diagnosis and adaptation design for hotspots with an LST ranging from 36°C till 41°C.

Remote sensing combined with GIS allows identifying the urban hotspots surrounding the parks, identifying the park areas adjacent to these (PAA), their surfaces and their land use, in order to design adaptation measures to increase the cooling capacity of these. In the case of South Holland provincial parks, most of the hotspots surrounding the park are adjacent to grassland patches. The measure to increase the cooling capacity of those patches would consist in a change of land use and an increase of the NDVI of the existing grassland patches. These suggestions to increase the cooling potential of the parks remain deliberately open in order to allow combining these measures with other spatial planning priorities.

5. DISCUSSION

The research questions presented in section 1.3. have been answered, as ultimately, this study provides a methodology to allow the development of design guidelines for the improvement of the cooling capacity of the park perimeter areas over the hotspots surrounding the parks. The provincial parks of such scale surely have a cooling influence in areas and cities located at a greater distance from the park; however such analysis falls outside the scope of this study. In any case, increasing the cooling capacity of the park edges contributes to increasing the cooling capacity of the park as a whole. The study delves deeper into the specific case of Midden-Delfland provincial park, to illustrate the proposed methodology, which could be replicated in the rest of South Holland provincial parks.

The first part studies how the different land-use categories encountered in South Holland parks (grassland, cropland, forests, water surfaces, built areas and industrial areas) present, during heat waves, different thermal behaviours (Indicators: night and day LST; and influencing parameters: average NDVI index, imperviousness coefficient, patch size and patch shape). It provides an overview of the correlation coefficient of the influencing parameters and the indicators, depending on the analysed land-use categories. The influencing parameters are patch characteristics which can be altered through design. Land-use and patch characteristics (within each land-use category) are the main design categories which have an influence on the thermal behaviour of the park.

The second part of the study aims at identifying park areas adjacent to urban hotspots surrounding the parks, where the implementation of cooling measures (identified in the first section) would contribute to the reduction of the urban heat of the adjacent hotspots. The exercise is carried out for the Midden-Delfland park. The hotspots are identified using Landsat 5TM imagery, the mitigating design measures are proposed for park areas adjacent to hotspots and presenting LST differences with the hotspots, below 10ºC. The idea is to use remote sensing and GIS not only to carry out the analysis of the cooling capacity of the park, but also to identify the areas that could benefit from the implementation of cooling design measures. The same technology for the analysis and for the implementation.

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Combining GIS and BIM for facility reuse

A profiling approach

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Abstract

Lingering vacant facilities deteriorate the condition of an urban environment, and, as a consequence, actuate neighboring companies to leave the area as well. In addition, new development efforts keep depleting scarce land resources. In this paper, a framework is presented to match existing vacant facilities to the requirements of potential customers or owners to promote sustainable redevelopment and reuse. Important attributes for facility reuse are identified from literature. To automatically extract these attributes from models and their surroundings, Geospatial information and Building Information Models (BIM) are combined. In the proposed framework, a profile is created for each existing vacant facility by combining BIM and GIS attributes. As a result, these profiles can be matched to the desired BIM model, which the aspiring users have provided, based on a weighted distance calculation. The framework presents the most suitable vacant facilities to the users in order to promote facility reuse. These facility reuse alternatives are evaluated based on a single monetary metric that represents the effort required to partially or fully accommodate the requirements of the aspiring users, which is reflected in the weighted distance between profiles from existing vacant facilities and the facility desired by the end-user. This framework identifies suitable areas for redevelopment after which a process is started that forms an iterative and comprehensive evaluation dialog between demand and supply parties, on multiple scale levels, including various design alternatives to adapt the existing facility to the desires of the consumer and revitalize the surroundings according to Geodesign principles. A proof-of-concept of the framework is presented together with the conceptual system structure. Evaluation of the attributes and the technical implementation of their extraction from BIM and GIS data show the technical feasibility of the approach.

KEYWORDS

Facility reuse; Geodesign; GIS & BIM integration; BIM

1. INTRODUCTION

1.1 Problem statement

Unlike regular urban development planning, industrial area development is mainly led and directed on the level of individual municipalities in the Netherlands, with the lack of participation of private real estate investors. The unrealism in new industrial area demand estimation, financial profitability of developing new industrial areas and mutual competition among municipalities all lead to the redundantly large supply of very cheap industrial area land plots (Blokhuis, 2010). As a result, a large amount of existing industrial areas are obsolete, with many abandoned facilities. According to the Dutch national industrial area database IBIS, 1052 industrial areas contain signs of obsolescence, equalling 32,230 gross hectares on January 1st, 2013 (Ministerie van Infrastructuur en Milieu (Ministry of Infrastructure and Environment), 2013). On the contrary, the Netherlands is well-known as a densely populated country, where land resources are scarce. Therefore, industrial area redevelopment and facility reuse are essential, as it can promote regional economies while using resources more efficiently.

In the industrial sector, land and facility reuse is not widespread. A lack of knowledge exists on vacant facilities and their potential for meeting the requirements of aspiring future users. Hence, new facilities are built while instead existing ones could have been reused. Reusing existing facilities is a more sustainable way for reducing the amount of disused, neglected and abandoned facilities and construction efforts.

For a sustainable future, facility reuse needs to be put on the agenda. It can serve as a main driver for land use redevelopment and suitable reuse strategies can democratize the planning process, which would allow private parties to participate and state their interest in a certain facility and its surroundings. Besides these advantages, the facility locations in many cases are historical sites, which are located centrally in large cities. Due to the spatial development of a given area, these buildings can often be heritage-listed and carry the character of a specific time period. This can be attractive to certain types of customers as it provides a sense of identity. From a financial point of view, it is claimed that reusing existing facilities saves 10%-12% investment over building new ones (Shipley, Utz, & Parsons, 2006).

Despite of the aforementioned points, land use planners tend to focus on a larger scale with a top-down perspective when dealing with industrial area redevelopment. On such a scale, details about individual facilities easily get lost, as information about this is not easily accessible.

Recently, more and more detailed building information models get available, due to technological advances as well as legislation required to get building permits. Incentives are thriving in countries like Singapore (Das, Leng, Lee, & Kiat, 2011) and South Korea (Zeiss, 2014). The availability of these models for detailed information about existing facilities enables new methods to stimulate facility reuse.

Research has been conducted on the usage of Geographic Information System (GIS), Building Information Modelling (BIM) and their integration mainly in the domain of Facility Management (FM). Rich and Davis (2010) provide a detailed overview of the application of GIS for facility management and the integration with other applications, including BIM. They conclude that in the field of facility management, combining GIS and BIM is helpful to ensure requirements are met and data that are needed at various stages of FM are captured. In addition, GIS analysis can help to find a suitable location for a new facility (Abudeif, Abdel Moneim, & Farrag, 2015; Panichelli & Gnansounou, 2008; Rikalovic, Cosic, & Lazarevic, 2014; Zhang, Johnson, & Sutherland, 2011). However, the implementation level of BIM within existing buildings is limited (Volk, Stengel, & Schultmann, 2014) which can be attributed to the fact that only recently BIM technology has become more popular. Notable exceptions include attempts to integrate BIM and GIS for emergency response and lifecycle management of a facility and its surroundings (Mignard & Nicolle, 2014; Shen, Hao, & Xue, 2012). However, research on BIM or GIS or their integration is limited within the scope of facility reuse. In this domain, the integration of GIS and BIM is of importance to connect geospatial information to detailed building level information to make informed decisions about the reuse suitability and possibility of existing vacant facilities.

1.2 Scopes and assumptions

For facility reuse, the emphasis not only lies on the physical facilities themselves but also on the surroundings. In this article it is assumed that successful selection of a facility for reuse is more likely when geospatial information and building information are both considered. In this way, an entire overview of how one facility functions in its social, geographic and demographic context can be constructed out of regional characteristics, building and encompassing plot attributes. In the scope of this article, a facility is considered to be a commercial or institutional building and its surrounding plot of land. And in one region, there are enough vacant facilities for reuse.

In this research, four general types of reuse are identified for an existing vacant facility, namely: occupying the existing facility only partially, occupying it entirely, using the encompassing plot for additional developments and, lastly, rebuilding another facility after demolishing the original (Figure 1). The natural resources that have been put into the building itself, makes the building the primary objective for reuse. Hence, the redevelopment process as outlined in this framework strives to accommodate facility reuse in the second category: completely occupying an existing facility. One could argue that searching for other existing facilities that match the demand of the aspiring owner more closely can fulfill the objectives behind the other three types of reuse.

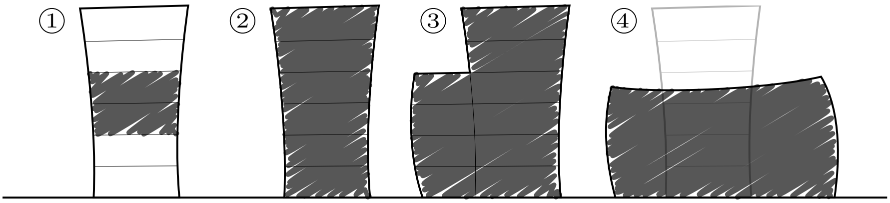


Figure 1. Four types of facility reuse.

1.3 Geodesign for better facility reuse

Facility reuse requires creative thinking and an integrated mindset of considering design alternatives for a building in conjunction with its surroundings. As such, it could benefit from principles outlined in the Geodesign methodology. Geodesign, as Flaxman has proposed and Ervin has amended, is a design and planning method which tightly couples the creation of design proposals with impact simulations, informed by geographic contexts, systems thinking and digital technology (Steinitz, 2012). It is the process of designing in a geospatial environment. Design assignments based on the Geodesign concept are performed globally (McElvaney, 2012). An example in an industrial context is the R2G project, which covers the transition of red fields into green fields, or change of abandoned and possibility contaminated areas into thriving public parks (McElvaney, 2012). In these cases, Geodesign processes and techniques helped to break down large and complex problems into components that could be analyzed. Furthermore, the Geodesign concept and techniques can be used to contribute to a more competitive and user-orientated decision process, which can attract investment and stimulate regional sustainable development.

In order to guide this process systematically, Steinitz has proposed a practical framework based on empirical research (Steinitz, 2012). This framework guides stakeholders by iteratively posing questions about the problem, the area, the process, the assessment results, and consequently creating more informed designs. Hence these guidelines are relevant in the context of facility reuse. After all, in order to understand the mechanisms behind its abandonment, the facility and its surroundings should be described along with the factors that drive changes on a geographical level. Furthermore, iterative thinking and the evaluation of design alternatives are of vital importance to successful reuse strategies.

However, Geodesign is still mainly discussed solely in a geospatial context. No specific attention has been given to incorporate building level information. For facility reuse the building level characteristics are essential to include in the design process. By combining GIS and BIM information, a better design can be obtained to satisfy stakeholder requirements.

In this way, Geodesign can be an instrumental tool for planners and facility owners, and can also gain a better understanding of the inner environment of the facility, its site and location within its broader spatial and social context.

In addition to the established Geodesign methodology, which starts with a specific project area in need of analysis and design, governments could adapt their Geodesign procedures by stimulating potential future users first to identify an area of suitable vacant facilities with the combination of GIS and BIM information. In this way, a collaborative design process, in which the most suitable project area or facility is not always known in advance, can be initiated, and the output of the framework proposed in this paper identifies areas to redevelop.

In addition, the framework proposes a singular monetary metric based evaluation method for different design proposal evaluations, which complies with the evaluation guideline of Geodesign process proposed by Steinitz (2012).

To conclude, the Geodesign framework and tools help to understand the facility and its surrounding, evaluate possible results for various design proposals and negotiate among stakeholders for a better final design. The proposed method provides a starting point for finding suitable facilities for further analysis and a simple evaluation paradigm for design proposals.

1.4 Objectives

As discussed in the problem statement, facility reuse is of great potential for sustainable development. In this chapter, a framework is proposed that enables public parties to accommodate facility reuse by private parties. It enables aspiring facility owners to match their criteria with characteristics of existing vacant facilities and discover those that are most suitable for redevelopment or reuse. A literature study has been conducted to find the most influential attributes for facility reuse and their data sources. In order to obtain such a system, data sources from both BIM and GIS are aggregated to provide stakeholders with a comprehensive overview of the facility and its geographical context. To aggregate different data sources, commonly used formats of GIS science and BIM are reviewed and possible integration methods are proposed. After data integration, a weighted distance calculation is applied, based on various attribute differences between the desired facility and existing vacant facilities. Aspiring owners can select a facility, based on a single monetary metric that is composed of the acquisition costs, and a monetary interpretation of the extent to which the existing facility might not meet all criteria set by the end-user. It is this single monetary metric that guides the evaluation of different facilities. Likewise, options for adapting the existing facility to meet all requirements can be evaluated iteratively. Guidelines from the Geodesign concept steer the conceptualization of the requirements. The effort is mainly directed at industrial facility reuse for promoting a regional sustainable redevelopment process to use resources more efficiently and provide economically more viable and desirable facilities to its users. Data sources and data integration are discussed. Several tools have been identified to extract attribute values from various heterogeneous data sources. However, an implementation and evaluation using real stakeholder data is beyond the scope of this paper.

In the following sections, a theoretical background for integrating GIS and BIM are presented and the framework and its proof-of-concept implementation are discussed. The technical implementation of the extractions shows the viability of the approach.

2. THEORETICAL BACKGROUND

2.1 GIS and BIM data formats

The Industry Foundation Classes (IFC) file format is a commonly used standard in the domain of BIM. It is spearheaded by the buildingSMART consortium and has been ratified as an ISO standard. IFC describes a building model as an assembly of building products, in which the products are composed of geometrical representations, semantic information stored as key-value properties, and relational information about decomposition and topological adjacency. IFC is based on STEP and has an EXPRESS schema definition, which defines the entities along their attributes and relationships that constitute a valid IFC file. IFC files are stored as either ASCII or XML files and are therefore human readable. Besides the definition of the schema, buildingSMART also standardises on sets of properties, which are plain text, to be used to cover common-use cases.

Other formats for describing building models exist, for example gbXML , or proprietary file formats which are native to commercial BIM applications. The former is primarily intended for use within sustainability analysis and is therefore not considered for inclusion into the system. Proprietary file formats, for which automated tools to extract data are not available, are not considered either as they would hamper the development of the system.

Conversely, in the GIS domain, shapefiles are a commonly used option for describing vector features. Rather than led by an industry wide consortium, this de facto standard has organically grown out of an initially proprietary format. Such a GIS database consists of a set of binary files. The geometrical information itself is separated over several files based on their types or layers. These geometrical entries define the location or perimeter of a feature in the world. Metadata records are stored in separate files that provide the semantics to these features. Overlap between, and ways to interlink, the different data carriers can be found on the building and site level, where GIS features describe the same building or site in a BIM model.

An IFC file has a default decomposition structure, which starts with a project and descends into a site, a building, individual building stories, down to individual building elements. Typically a building does not have a geometrical representation of its own, but is geometrically defined as the composition of its elements. In the GIS domain, the building footprint is represented as a polygonal boundary. Attributes can be applied to the polygonal boundary, such as the building height or the functional characteristics of the building it refers to. In IFC the site can have a geometrical representation, but there is no guarantee that it is aligned with any of the footprints in the GIS system or in the cadastral records. The IFC standard primarily intends the site to be used for documenting the construction site. As defined by the IFC standard, a site does have an optional definition of a single geographic reference point, specified by its latitude, longitude and elevation. This is a key factor for being able to link a building model to a feature in a GIS database, as string-based building identifiers are error prone and context specific.

In addition, hybrid formats intended for use on an intermediate scale exist. For example, the CityGML format , which is an XML based standard led by the OGC . It lacks the semantic, topological and parametric richness to convey constructed documentation as can be found in an IFC document, but is suitable for documenting urban environments in three dimensions. The use of CityGML is currently not considered for this prototype, as public datasets on an urban scale are not available within this project.

2.2 Combining versus converting

Despite the differences in how data are stored in the GIS and BIM domain, the attributes that are relevant for this prototype system implementation can be extracted into a uniform tabular structure of attributes. This method is different from other strategies found in the literature, for example on building an integrated system by converting one format into the other. The translation from IFC to CityGML is discussed in (Isikdag & Zlatanova, 2009; Nagel, Stadler, & Kolbe, 2007). On a building scale the expressiveness of IFC is richer than CityGML in most aspects; such a translation to a large extent boils down to converting the solid volume representation in IFC into merely the visible surfaces for use in CityGML and mapping the classes. Conversion the other way around is more difficult, due to richer semantics required to constitute a meaningful IFC, as has also been reported by (De Laat & Van Berlo, 2011; EI-Mekawy, Ostman, & Hijazi, 2012; Isikdag & Zlatanova, 2009) and due to lack of solid volumes. As such, in this paper, we combine GIS and BIM data sources for the purpose of facility reuse without the associated loss of information of converting data formats.

2.3 Guidelines for integration

The presented approach is based on a combined feature extraction method and therefore does not rely on a shared common denominator between the BIM and GIS input formats. This results in a modular system in which interdependencies between logic for BIM and GIS processing can be eliminated and both domains can be queried up to their full potential without information loss.

On the other hand, the loose coupling, has urged to come up with guidelines and best practices for modelling seamless inter-linkage between the two input streams in order to reduce manual effort and errors in data curation.

The geospatial database is the starting point for implementing the framework. BIM models can incrementally be added into the system. In order to be able to associate the BIM model with the geospatial information, the building model needs to have a georeferenced point. In this way, the distinct domains can be integrated to enable the coupled feature extraction. This association takes place on two levels. Firstly, by means of the georeferenced point, distances to important geospatial features can be computed and land use and other relevant geospatial data can be incorporated. However, in order to link to the attributes related to the GIS feature, the BIM geospatial reference point needs to be contained within the polygon of this building in the GIS. Therefore, the link can be established by a point-in-polygon test. If geo-reference is not supplied in the IFC file, interlinking the two needs to be done manually in a graphical user interface.

In general the extracted information from the GIS and BIM domain may need to be curated upon ingesting the information into the system.

3. IMPLEMENTATION

3.1 Framework

The framework suggests existing vacant facilities to potential customers aspiring to acquire industrial facilities. Prospective owners are asked to provide detailed information, preferably a BIM model, about their ideal conception of a building. The framework then composes a vector of quantitative measures that describes aspects of the building and its relation to geospatial resources. Examples of these measures include properties like the floor area and ceiling height of the facility, derived from the document or BIM they provide. Furthermore, distance to, for example, public transport hubs and supply chain partners can be derived from GIS. Lastly, the outcomes of simulation or measurement can be included, for example the indoor lighting levels on working height expressed in lux.

Thus, within this framework, for abandoned or vacant facilities, a profile is extracted by combining data from BIM and GIS. These can be matched to the requirements supplied by the prospective owner. A set of the profiles, that resemble the demand vector, can be presented to the prospective users. This set consists of the profiles for which the weighted Euclidian distance to the demand profile vector is relatively small, based on predefined thresholds. As such, they represent vacant facilities that closely match the desired facility as sketched by the client. This framework enables a win-win situation in which, on the one hand, the requirements from the potential users are fulfilled and, on the other hand, existing vacant facilities are matched for redevelopment. The profiling approach presented connects supply and demand for a sustainable future.

3.2 Attribute identification

A list of prominent attributes for facility reuse is identified and presented in Appendix A. They are categorized into building-level attributes, building plot and geospatial characteristics and demographic properties. The identification of the attributes is based on a literature review (Bottom, McGreal, & Heaney, 1998; Geraedts & Van der Voordt, 2003; Glumac, 2012; Korteweg, 2002; Remøy, 2010; Stichting Real Estate Norm Nederland, 1992; Van der Voordt & Van Wegen, 2005).

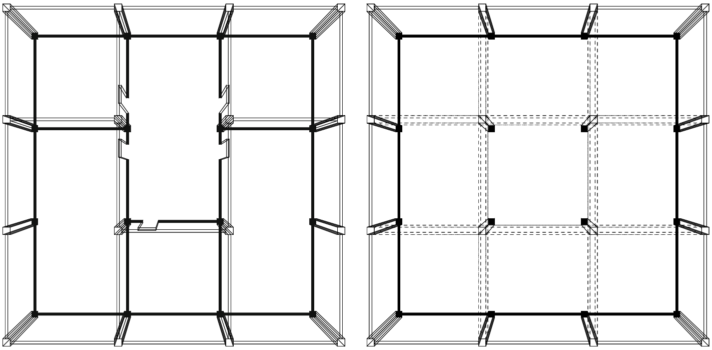


Figure 2. An illustration of the openness of an architectural space, quantifiable by dividing the volume of spatial separation elements (such as walls, columns and beams) by the volume of the spaces itself, to be extracted from the BIM. The architectural openness can be seen as a measure for the flexibility of the facility.

Figure 2 illustrates one of these attributes for two distinct facilities. The objective is that all attributes are unambiguously quantifiable and extracted automatically without user interpretation from the building model or geospatial and statistical information sources. Additionally, attributes are classified according to their level of measurement, whether they are numeric or nominal. Data sources for Dutch cases and references to the tools for automatically extracting or calculating these attributes are also provided in Appendix A. For implementation into other target areas, this list of attributes will likely have to be tailored to this area.

3.3 Distance calculation

The vacant facilities span an n-dimensional search space, in which n represents the size of the set of identified attributes. Every vacant facility occupies a point in this space, as does the desired facility, presented to the framework by the prospective owner. The vacant facilities that are close to the desired facility are selected and presented to the client as recommendations. The relation between these facilities can be visualized by means of their attribute values. Key distinguishing attributes can be represented as an axis in an overview to the user. In such way the user can initiate an interactive negotiation process in which the set of vacant facilities is explored. A graphical depiction of this overview is presented in Figure 3.

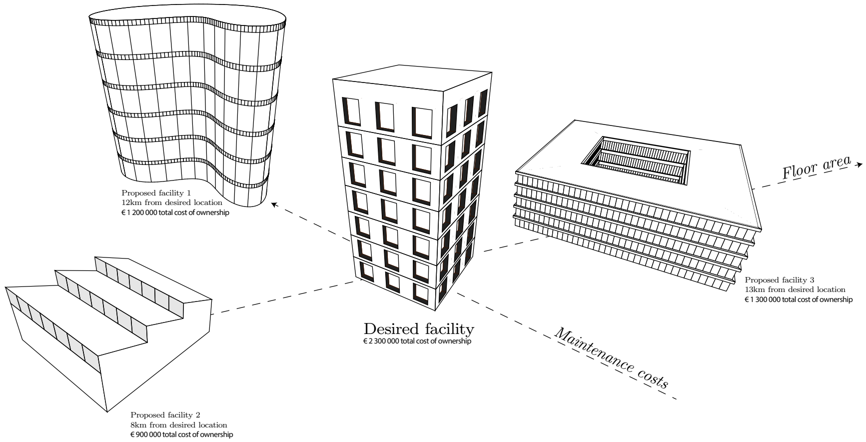


Figure 3. A schematic representation of the facility selection process in which several axes, representing the attributes at which the facilities differ, are presented to the user together with the renovation costs.

The formula used to calculate the distance between the desired facility and the existing facilities is shown below.

$$d = \sqrt{\sum_{i=1}^{n} \omega_i \, f_i(x) \, x^2}$$

Where d is the weighted distance between an existing facility and the desired facility in the n-dimensional search space, n is the size of the set of identified attributes. Each of the identified indicators is assigned with a weight _i according to the stakeholder evaluation. x is the normalized difference between the actual facility value and the desired value for each attribute. Furthermore, f_i (x) is a fuzziness function (Beg & Ashraf, 2009; Chaudhuri & Rosenfeld, 1996; Montes, 2007) that can be used to model asymmetry and vagueness inherent to the attributes. This will be explained in the next section.

3.4 Fuzzy theory

Suppose the client requires a minimal ceiling height of 4 m due to regulations and if one were merely using the squared difference (x^2), this would lead to the surprising assumption that a ceiling height of 4.5 m is as preferable as 3.5 m. This is clearly not the case, as the latter violates the regulations. As a second example, suppose the client suggests a minimal floor area of 40 000 sq.m. Surely some tolerance is desirable, so that a facility of 39 800 sq.m is still matched. Both these aspects, the asymmetry and the imprecision, are modelled by the fuzziness function. Note that this function is tailored to the attribute and varies, based on whether the user specifies a minimum or maximum value. In some cases this function can also simply be a constant f_i (x)=1. Figure 4 illustrates a possible fuzziness function for the ceiling height example, where is the standard deviation of the existing vacant facility attributes' values. As the normalized difference approaches – the weighted distance will approach infinity, rendering this facility unsuitable for selection due to the large distance, whereas when the requirement is met, the function trends towards zero, diminishing the weighted distance.

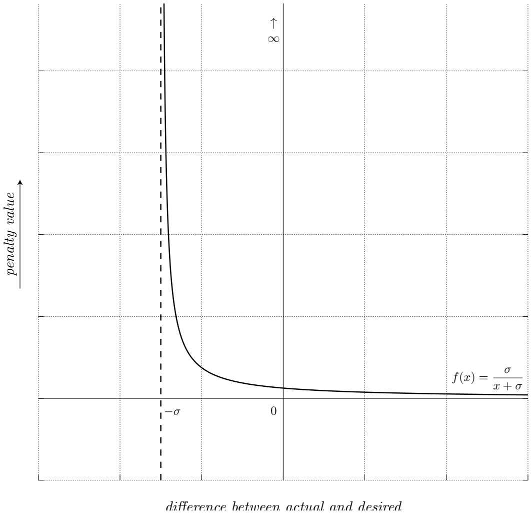


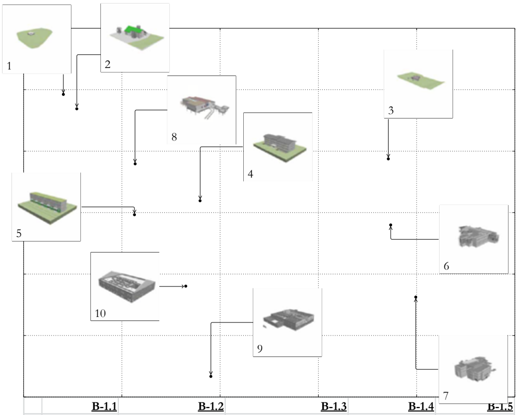
Figure 4. A possible fuzziness function for a minimum value attribute.

3.5 Monetary based negotiation

As discussed in the previous section, some attribute requirements might not be fulfilled completely by means of the selection process. It is important to realize that the method presented in this paper entails an iterative negotiation process between the demand and supply parties. Unmet requirements are not necessarily insurmountable. For example in the case of the attribute sketched in Figure 4, it is easy to see that by architectural remodelling the two spaces can be made more equivalent, a transformation that comes with a monetary cost. Therefore, the selection process lead by the client can be monetary based, with many of the attribute differences represented as monetary measures. For each of the suitable vacant facilities suggested to the customer, a monetary indicator can be composed that reflects the acquisition, renovation and maintenance costs and can also incorporate costs related to geospatial business risks like crime rates and employment conditions. The redevelopment costs can be tailored to a specific client, industry and spatial context. Thus, the prospective owner is able to select amongst the vacant facilities and can compare the associated costs with the projected costs for establishing a newly built facility by means of a unified monetary measure.

3.6 Proof-of-concept

In order to prove the concept of our system, Dutch data sources are explored to give insights to future users where to obtain data (See Appendix A). Since GIS is commonly used in the field of Geodesign, calculating and extracting data from ArcMap is not discussed here.



	B-1.1	B-1.2	B-1.3	B-1.4	B-1.5
	Net floor area	Restroom floor area	Architectural openness	Building height	Ceiling height
1	79.596	3.752	4.568	3.920	2.300
2	97.270	3.348	5.140	5.530	2.480
3	4648.428	16.727	42.623	12.000	3.800
4	2266.660	102.080	8.303	12.000	3.000
5	909.811	206.849	8.403	10.740	2.780
6	5100.000	245.442	46.331	11.700	3.700
7	11728.758	105.826	16.730	20.000	4.000
8	477.682	54.844	7.294	9.450	3.200
9	6935.799	910.335	13.581	10.250	4.680
10	3582.008	384.390	8.703	7.925	4.267

Figure 5. A demonstration of automatically extracting attributes from IFC building information models.

In order to demonstrate the feasibility of automatically extracting attributes from IFC building information models, a list of such attributes is presented for a selection of publicly available IFC models . A graphical interpretation of this data is shown as well (Figure 5). This plot uses a multi-dimensional scaling algorithm that tries to preserve relative distances of the samples while embedding their multi-dimensional space into the rendered two-dimensional plane. As such, similar buildings are presented close to each other. Attributes pertaining to building areas are either to be found in IfcPropertySets on an IfcBuilding level, or if absent, aggregated over the various IfcSpaces in the model. Ceiling height and building height are deduced from the Elevations of the IfcBuildingStoreys. Architectural openness is computed from the solid volumes of the IfcRepresentationItems of IfcSpaces and IfcWalls, which are computed by an open source software toolkit for IFC files, called IfcOpenShell . With the attributes extracted from the confluence of GIS and BIM, they can be incorporated into the proposed system for selection by end-users.

1. Upload a model of your desired facility

A list of building-related attributes will be automatically extracted from your building model that will guid the search for existing vacant facilities.

If you do not have a digital building information model you can provide a list of building-related attributes that are important yourself.

If your building model is geolocated, information from the GIS system is imported. Otherwise, a target location can be specified to gather the data from or, alternatively, a list of attributes related to the surroundings can be provided. This will guide the search for existing vacant facilities as well.

2. Review the list of extracted attributes and apply weights

Building						
Layout						
☑	5	B-1.1	Net floor area	approximately	5000	m^2
☑	3	B-1.2	Restroom floor area	at least	100	m^2
☐		B-1.3	Architectural openness			
☐		B-1.4	Building height			
☑	4	B-1.5	Ceiling height	at least	2.6	m
Period						
☑	3	B-2.1	Year of construction	at most	1990	
☐		B-2.2	Last renovation year			
☑	1	B-2.3	Vacancy period	at most	2	years
Entrance, accessibility, circulation						
☑	3	B-3.1	Private entrance		yes	
☐		B-3.2	Reception and waiting area			
☐		B-3.3	Loading bay			
☐		B-3.4	Accessible for the disabled			

3. Review the suggested facilities

4. Show differences in attributes and estimate costs

General								
☑	G-1.1	Acquisition costs			€ 1 712 000			€ 1 420 000
☑	G-1.2	Maintenance cost			€ 582 000			€ 412 000
Building								
Layout								
☑	B-1.1	Net floor area	4551	m^2	€ 22 450	4815	m^2	€ 9 250
☐	B-1.2	Restroom floor area	130	m^2		110	m^2	
☐	B-1.3	Architectural openness	0.9			0.81		
☐	B-1.4	Building height	6.2	m		16.8	m	
☐	B-1.5	Ceiling height	3	m		2.8	m	
Period								
☐	B-2.1	Year of construction	2001			1992		
☐	B-2.2	Last renovation year	-			-		
☐	B-2.3	Vacancy period	1.7 years			1.2	years	
Entrance, accessibility, circulation								
☑	B-3.1	Private entrance	yes			no		€ 23 000

Total estimated costs	€ 2 712 800	€ 2 132 100

Figure 6. A screenshot of the proposed framework outlining the steps involved of using the system.

Figure 6 shows a screenshot of a proof-of-concept implementation of the system discussed in this article. It outlines the procedure that the end-user will follow when using the system to get suggested facilities based on a digital building model of his required facility.

At the first step, the potential users are asked to upload their desired facility BIM model to the system so that several of the attribute values can be automatically extracted by the system. In case no building model is available, the user can complete the list of attributes manually. If the building model is georeferenced, geospatial and demographic information is extracted from the GIS seamlessly, otherwise a geolocation needs to be specified by the user to guide the same process.

Secondly, the user can apply weights to these identified attributes and curate the extracted values where necessary. The user is able to indicate whether these values signify minimum, maximum or approximate values, which is reflected in the weighting function explained above.

Based on the combined attributes extracted from BIM and GIS, the system composes the demand profile and calculates the distance with each of the available vacant facilities by applying the formula outlined above. The most similar vacant facilities are presented. The vacant facility information is provided by the supply party of industrial facilities. This includes building information models and geospatial characteristics. Even though policy makers realize the importance of building information models, there is are not many publicly available BIM models.

Conclusively, in an iterative design process the user can evaluate the attributes once more by assessing their impacts on the projected expenses of acquiring the facility and adapting it to match the initial requirements. Note that not only costs associated to the building itself are estimated, but differences in the geospatial attributes are reflected in the evaluation as well, as they represent risks associated with the demographic and spatial characteristics of the target area.

4. DISCUSSION AND CONCLUSIONS

Facing a severe vacancy of industrial facilities, a challenge is evident to solve negligent depletion of land resources. In this paper, a framework is presented to match existing vacant facilities to the requirements of potential customers to promote sustainable redevelopment with possible private investors involved. The concept of Geodesign acts as a framework for iterative evaluation on multiple scale levels and can be formally initiated after stakeholders have used the proposed framework to identify an area for redevelopment. In order to facilitate the evaluation of attributes that have an asymmetric nature, the framework applies concepts from fuzzy theory. In addition, a simple straightforward monetary based evaluation paradigm is presented for the purpose of facility reuse. The proposed framework complements the set of tools that concurrently Geodesign professionals have at their disposal.

To conceptualize this framework, a literature study has been conducted to identify important attributes for facility reuse, both on building level and on regional level. In this way, geospatial information and building information can be seamlessly combined. These attributes are classified based on their scale, source and type. For integrating geospatial information and building information, a theoretical background is illustrated considering data formats, integration possibilities and the preferred way of integration by extracting relevant attributes without interoperability problems. In the appendix, possible data sources and ways to extract or calculate attribute values for Dutch cases are presented. The implementation of extraction proves the feasibility of the approach suggested in this paper.

The framework is designed to provide a comprehensive and effective way to stimulate facility reuse. The methodology outlined in this paper is of a general nature and relevant to various situations. Nevertheless, several aspects are still to be addressed in future research.The way to determine vacancy of a facility varies based on local situations and regulations. It can be estimated by means of employment rate or the usage percentage of floor area, but general unified measures of required detail are not always present. Thus, a pre-consultation with supply parties is essential.

In general, at this moment, implementing this framework on a global scale is not feasible due to the fragmentation of data sources and regulations. This is not necessarily detrimental for a further investigation of this concept, as aspiring owners of facilities are likely to have a clear target location in mind to house their facility before consulting this system. From the proof-of-concept implementation presented in the previous section, it can be seen that this framework and system can be modified and applied in other areas once the data are available. Therefore, it is possible in future research to verify and validate the applicability by means of a case study in a specific area with actual stakeholders, preferably with the help from supply parties and local governments to acquire the necessary data.

Moreover, the Geodesign concept helps in understanding the facilities and their incorporation in their social and geographic context. Following this methodology, the facilities are not isolated from the environment and alternatives are evaluated based on the importance that stakeholders have defined not only on a building level, but also pertaining to the building plot and its geospatial relations. In addition to the monetary evaluation, a more visual representation of the difference in attributes can be presented, based on future research that might appeal more to people with a design background. As have been illustrated, the framework not only initiates the Geodesign process by providing possible facilities for reuse, but also provides guidelines for further iterative evaluation and assessment of various reuse designs in a geospatial environment. Though current evaluation is solely monetary-based, further research can be performed for more holistic evaluation according to future user requirements.

As discussed in the section on data acquisition, common guidelines about BIM and GIS data interoperability can be provided to the future stakeholders so that systems such as these, that build on a combination of the two sources of information, but also other efforts related to BIM and GIS harmonization, can flourish.

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EDUCATION

Bringing geodesign to the world in a massive, open, online engagement

‘Geodesign: change your world’

KELLEANN FOSTER

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Abstract

A MOOC titled “Geodesign: Change your world” demonstrated a unique approach to scaling up awareness about geodesign to a global audience. Massive Open Online Courses (MOOCs) are gaining visibility as a wide-reaching educational trend to provide exposure on topics, theories and techniques in any field. The first MOOC on the subject of geodesign was offered in Autumn 2014. Over 17,000 people registered from 167 countries. The results yielded a unique worldwide conversation about geodesign. This paper discusses how this MOOC engaged a global audience of thousands, including the challenges and opportunities experienced with the development and delivery of the MOOC. The outcomes illustrate how participants gained appreciation for the role geodesign can play in land planning and design issues in their location. The Geodesign MOOC course’s dynamic structure breaks from the typical format of MOOCs. Examined here are the innovative course design and delivery mechanisms deployed in this MOOC. Drawing on recent research about online learning, pedagogical and technological issues important to consider in MOOC development are reviewed.

KEYWORDS

Geodesign; MOOC; Distance Education; GIS; Collaboration

1. INTRODUCTION

There have been nine international conferences (Geodesign summits) focused on geodesign in the past five years and each year a growing number of publications mention geodesign, but yet, overall, geodesign is still considered a fairly new term and an emerging field (Wilson, 2014). The author is an educator responsible for advancing understanding about this new field; one which our university has invested in by establishing new online graduate programs in geodesign. Due to these circumstances, the possibilities of what a MOOC could provide were intriguing. MOOC is short for Massive Open Online Courses. MOOCs are classified as "virtual, distributed classrooms" (Kizilcec, Piech, & Schneider, 2013, p. 170). They are offered primarily as asynchronous courses and centralize all course resources in the cloud (de Waard et al., 2011). MOOCs are gaining visibility as a wide-reaching casual educational trend to provide exposure to topics, theories and techniques on any subject. A MOOC is usually an individual course (versus a series), very large (typically in the thousands), free for anyone, anywhere – that is, the "open" part, offered via the internet, and it is (typically) not awarded college credit. There is no "entrance" requirement other than access to an online connection and standard internet browser software.

MOOCs began in 2008 and started gaining traction in 2011. They were on a grow curve but appear to have levelled out in 2013 (Miller, 2014). There are three primary MOOC providers: Coursera (www. coursera. org), EdX (www. edx. org), and Udacity (www. udacity. com) (Robinson, 2013). Universities subscribe to a provider, which means they are buying access to a database of millions of potential students. Coursera, for example, has nearly seven million users, worldwide (Perna et al., 2014; Robinson et al., 2015).

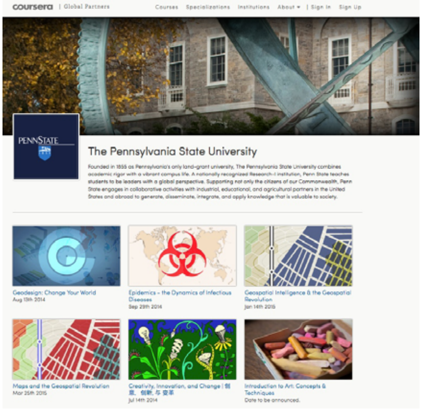
MOOC courses can vary in length from four to twelve weeks. Research shows that participation in MOOCs slows after the second week and really begins to trail off after four weeks (Straumsheim, 2014; Perna et al., 2014). The subject of this paper is a Geodesign MOOC titled: 'Geodesign: Change your world'. It is five weeks in length and was offered for the first time August-September 2014.

As with any new subject or terminology, the early players to the dialogue can have a strong influence on its future. The potential global reach that a MOOC provides served as a strong incentive to the MOOC development team to become a larger player in the discourse that is continuing to define and shape geodesign. Something similar can also be said with respect to new education mechanisms. Though MOOCs are relatively new, pedagogical and technical issues have been raised regarding MOOC participation and effectiveness (Yousef, Chatti, Schroeder, & Wosnitza, 2014). The structure and approach to this Geodesign MOOC sought to address these.

2. GEODESIGN MOOC BACKGROUND

The Geodesign MOOC's sponsoring institution, Penn State University, is not new to online course offerings. The University's World Campus has over fifteen years of success in offering courses and degrees solely online (www.worldcampus.psu.edu/about-us). Along with the services of a World Campus instructional designer with online expertise, within the MOOC development team's home college there is also a resource for creating online courses: the eLearning Institute. Additionally, the new online graduate programs in geodesign are in partnership with the University's Geography Department. Their long track record of success with an online Master of Geographic Information Systems (MGIS) degree, and the development of a Maps MOOC one-year earlier, enabled them to contribute valuable mentorship to the Geodesign MOOC team. This combination of expertise and resources served as impetus to proceed with preparing a Geodesign MOOC.

Penn State University signed on as a Coursera partner in February 2013. The University has a limited number of MOOC course slots; for that reason, and to monitor the quality of the proposals, there is a competitive two-stage review process to determine who can offer a MOOC. The Geodesign MOOC development team became aware of this opportunity when Geography started preparing a Maps MOOC in 2013. The Geodesign MOOC is part of the second round of MOOC courses authorized from Penn State University (Figure 1). Some MOOC courses are purely thought-leadership; some are closely tied to current online degree programs. The Geodesign MOOC is a combination of both of those reasons for doing the course.



The Pennsylvania State University

Founded in 1855 as Pennsylvania's only land-grant university, The Pennsylvania State University combines academic rigor with a vibrant campus life. A nationally recognized Research-I institution, Penn State teaches students to be leaders with a global perspective. Supporting not only the citizens of our Commonwealth, Penn State engages in collaborative activities with industrial, educational, and agricultural partners in the United States and abroad to generate, disseminate, integrate, and apply knowledge that is valuable to society.

Figure 1. MOOC provider Coursera's list of Penn State University Courses.

2.1 Motivation to pursue a MOOC

There appear to be no generalizable motives for why a MOOC is produced. "Motivations vary from philanthropy/altruism to marketing/branding to future profit-making" (Bali, 2014, p. 44). The Geodesign MOOC development team's motivation for creating their MOOC touches on these and is centered on three chief purposes. The first is that the term geodesign is still new enough to have a variety of conceptions about it (Artz, 2010; Flaxman, 2010; McElvaney, 2013; Miller, 2012; Steinitz, 2012). The development of the Geodesign MOOC was based on the team's strong desire to help shape dialogue regarding this emerging form of land design and planning practice. In particular, the authors of the MOOC are in a school of landscape architecture and seek to reinforce recognition that geodesign is a collaborative process, with design as one of its core components (Foster, 2015). The Geodesign MOOC development team believes a MOOC affords a unique opportunity to clarify and advance their perspective on what geodesign is (or should be) and what it is not, and to help steer the dialogue in a specific direction. The primary motivation for doing this MOOC is to provide thought-leadership about geodesign.

The second motivation for undertaking a MOOC is to expose new audiences to geodesign. There is a strong interest in exploring the role that technology can play to broaden access to this content (Lang, 2014). As a Coursera partner, there is potential for this MOOC to have a very broad reach. Heavy promotion through a variety of channels was also paramount to reaching a diversity of students. Due to MOOCs being low-stakes and free, they provide an excellent way to expand awareness about geodesign to many who would likely have never heard about it otherwise.

The third motivation for doing this MOOC is to enhance visibility about educational opportunities in geodesign, which includes the sponsoring university's new online geodesign graduate programs. Many online courses for credit target working professionals who seek career advancement without relocating. A MOOC expands that audience to include individuals pursuing continued personal growth. Research shows that MOOCs attract life-long learners (de Waard et al., 2011; Koller, 2012). Because there are no entrance requirements, MOOC students can be at any stage of a career and from any background (Kizilcec et al., 2013). Some who take a MOOC may be interested in exploring the course's key concepts further.

2.2 Course Goals

MOOCs continue to evolve and each course is based on its own underlying priorities (de Waard et al., 2011). As discussed above, a key motivation for undertaking this MOOC is to provide thought-leadership about geodesign. To support that desire, four key goals were identified to guide creation of the Geodesign MOOC.

The initial focus is the importance of offering this at a very introductory level; the team did not want to lose students in jargon and minute details. We correctly surmised that most students were not aware of geodesign prior to the course. The first goal is to create a geodesign "gateway" experience. Covering basic concepts about a subject is a common approach for MOOCs (Miller, 2014).

The second goal is to raise the level of excitement about the possibilities for positive change in a place. This goal is of personal significance for the course faculty author. It is based on the desire to instil hope in the students. One of geodesign's tenets is its potential to empower people (McElvaney & Foster, 2014). The course author wants to assist students in understanding how they can participate in advancing desired change in their community.

The Penn State University geodesign graduate program's advisory board of national experts highlighted the third goal. They insisted the course must inspire students through real-world examples of geodesign from across the globe. With an anticipated global audience, avoiding being too USA-centric can enable students to find relevance. A diverse set of case study examples were curated and are discussed below.

The last goal, related to the others, is the course faculty author's desire to have this MOOC encourage a global conversation about issues surrounding change in a place (Figure 2). In particular, the potential to approach how land design and planning challenges can be handled differently – specifically how the geodesign process can facilitate desired change.

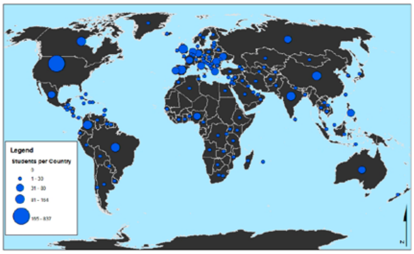


Figure 2. Map of Geodesign MOOC course enrolment numbers by location.

3. COMPONENTS TO ENHANCE MOOC SUCCESS

Increasingly both the conversation and research about what constitutes success in a MOOC is shifting. Sharp criticism has been levelled that the percentage of student completion rates are too low (de Waard et al., 2011; Miller, 2014; Stenger, 2014; Yousef et al., 2014). This perspective is slowly being replaced by other means of assessing MOOC success. There is growing understanding that different types of student learners seek different educational experiences and ways of gaining new knowledge – and not all desire an official statement of accomplishment awarded to those who satisfactorily complete all MOOC course requirements (De Waard et al., 2011; Kizilcec et al., 2013; Straumsheim, 2014). There are a variety of findings aimed at understanding what approaches may yield more effective online teaching. For this paper, those also well suited for MOOC instruction are curated and discussed. They are provided to address attaining successful MOOC outcomes, defined here as student-identified satisfaction via post-course self-reflection feedback and surveys. These findings are primarily pedagogical issues, with some related to technological issues, which MOOC course designers should be mindful of when creating a MOOC.

The research points to seven pedagogical and platform issues with noted impact on MOOC quality and student success:

- More than lectures as content
- Student motivation & engagement
- Assessment
- Organization & structure
- Differential learning styles & Accessibility
- Application of new knowledge
- Online Platform Issues

Naturally, several of these are interrelated; however reviewing each reinforces the potential opportunities for overcoming concerns about the MOOC educational experience.

3.1 More than lectures as content

The original method of instructional delivery for a MOOC was the recorded video lecture. Many MOOCs still follow this format; however, relying on video of a standard 'talking head' lecture as the primary method of instruction is now recognized as one of the least effective ways to deliver educational content online (Koller, 2012; Robinson et al., 2015; Straumsheim, 2014). Videos most certainly can and should be used, but it is best if they comprise only part of the course content and are properly designed. When determining content for a video, course authors should adhere the 'segmenting principle', which is a key multimedia instructional tenet (Miller, 2014, p. 155). It is particularly beneficial to students who are new to the subject matter to deliver that information by dividing it into shorter segments, preferably about ten minutes in length (Miller, 2014; Norvig, 2012). Providing content in a variety of formats and organized as modules is a best practice, including incorporating active learning (Lang, 2014; Straumsheim, 2014). For this MOOC, in addition to the video lectures, content is offered that highlights geodesign through mapped and hyper-linked case study examples, targeted readings, and interactive activities, such as exploring alternative design scenarios.

3.2 Student motivation & engagement

Free courses are particularly susceptible to student distraction and disengagement. There are plenty of interesting things on the internet – what will keep students motivated to return each week? Additionally, large online courses can seem particularly impersonal, so recognizing the social needs of students is an important consideration. For MOOCs, the course instructional design is paramount to manage for active student engagement (Miller, 2014). Students respond best to repeated opportunities to review and practice the key concepts (Lang, 2014). Proper design of assignments and activities, seeded-prompts in discussion forums and fostering voting on peers' discussion forum posts can contribute to engagement (Robinson et al., 2015). This MOOC begins with an introductory interactive map as a social connector to help engage students and make it feel less impersonal (Head, 2013; Robinson et al., 2015). The map immediately immerses students in spatial issues central to geodesign by having each student self-locate and contribute something about themselves related to their interest in geodesign.

3.3 Assessment

One study clearly showed that "learning analytics and assessment" were key features in MOOC effectiveness (Yousef et al., 2014, p. 48). Providing regular feedback to students on their progress helps them understand and "improve their learning outcome" (Yousef et al., 2014, p. 46). This is often accomplished with short, weekly quizzes. With the massive student numbers in a MOOC, it can be difficult to provide detailed, personal assessments. A unique way to address this has emerged in form of peer-grading of assignments (Luo, Robinson, & Park, 2014). Related to student engagement above is the value in having students become fully engaged in course content through evaluating their peers' work. Along with that desired engagement, the peer assessed assignments also represent a valuable learning strategy because students discover and grow from that experience (Koller, 2012; Luo et al., 2014). This MOOC deployed peer assessment of the final activity, which relates specifically to geodesign – each student submitted their outline of a geodesign challenge. As discussed previously, there is increasing recognition that many MOOC learners do not need or seek assessment of their learning progress (de Waard et al., 2011; 2014; Kizilcec et al., 2013; Straumsheim, 2014).

3.4 Organization & structure

Most recognized instructional design approaches stress the importance of a well-organized course to help students frame their learning (Miller, 2014; Yousef et al., 2014). Additionally, the content of lectures and their organization are also found to be an important factor in MOOC success (Yousef et al., 2014). There is also considerable value in using a graphically visual calendar to help students get an overall grasp of the course structure (Kizilcec et al., 2013; COIL, n.d.). The course's objectives and schedule must be clearly defined for students from the very beginning of the MOOC (Yousef et al., 2014), and reinforced again each week. It is important to remember that a MOOC should not be treated the same as a traditional classroom course (Bali, 2014; Straumsheim, 2014). The aforementioned principle of "segmenting" (Miller, 2014, p. 155) can also apply to how the course is organized; chiefly: in modules. Modules can, for example, introduce a topic in different formats or the same topic divided into different parts (Straumsheim, 2014). Modules can reinforce each other, but each is also discrete; this means that if a student does not view every module, the goal of introductory exposure to the topic may still be satisfied. This MOOC is organized in modules to provide consistent structure each week with diversity of content delivery as discussed above; modules are discussed below in section 4 (Outcomes).

3.5 Differential learning styles & accessibility

The sheer quantity of students and the fact that MOOCs have no entrance filters means that there will be a wide variety of student abilities, learning styles, facility with language, and accessibility issues. The MOOC instructor should be cognizant of accessibility, particularly for students from locations with bandwidth or other online access limitations (Kizilcec et al., 2013). People process information in different ways, referred to a "VAK: Visual Auditory Kinesthetic" (Miller, 2014, p. 150). In other words, some people prefer a graphic modality; some process better via spoken word; and others prefer making activities. In point of fact however, it is how these modalities are combined that is most important (Miller, 2014). Providing instruction in a variety of modalities enables a wider range of students to learn more effectively. For example, "narration works best when it uses conversational … language", and it is not verbatim of text on the screen (Miller, 2014, p. 154). The aforementioned discussions about video lectures should also be considered related to differential learning styles and accessibility. It is a best practice to include, along with the video, the written text of what is spoken in the video and any included graphics (Robinson et al., 2015; Yousef et al., 2014). Furthermore, the recorded lecture itself should not be just the professor talking, but rather seek to engage visual learners, which is the majority, by incorporating illustrations or graphics that directly support the concept being discussed. And the video and accompanying text can go further by deploying the "signaling principle", which advocates highlighting key points so they stand out (Miller, 2014, p. 155). The goal here is to enable each learner to proceed at his or her own pace (Koller, 2012). The fact that a MOOC is asynchronous and videos can be slowed down as well as watched multiple times, or read instead of watched, can be an advantage in achieving this. With geodesign rooted in spatial issues and place-based design principles, the MOOC faculty author could easily address this component through the generous use of graphical examples specific to these issues and principles.

3.6 Application of new knowledge

A strong concern voiced about MOOCs is that they typically provide little or no opportunity for students to apply their new knowledge (Stenger, 2014). Deeper reflection about the subject is desired (Bali, 2014). This can be a challenge due to the scale of the class size, the uneven skill level of the students and the typically introductory nature of MOOCs. There are two instructional techniques that can be used to address this need: thoughtfully detailed discussion forums, and assignments that go beyond basic auto-graded responses. As discussed above in the section on Student motivation & engagement and in the section on Assessment, there are exciting ways to foster dialogue within the discussion forums that can ask students to think more deeply, and requiring an assignment prepared by the student that is peer reviewed will necessitate that students apply what they have learned.

3.7 Online platform issues

The MOOC providers have a robust platform that scales to accommodate thousands, but that may also mean it is less forgiving in how a course is structured (Head, 2013). As mentioned, MOOCs evolved from a video-biased format. Both of these issues may require some creativity to overcome these limitations in order to address issues outlined above. An important distinction in massive online instruction, which can be a huge factor in determining content, is that MOOC's do not fall under the United States' 'fair use' educational standards (Smith & McDonald, 2013). If the provider is a for-profit company, such as Coursera, then MOOCs must receive permission for any content except for direct links. The Geodesign MOOC course faculty author contacted one publisher for permission to use an paper and the response was to have each student pay individually $2.00 per copy. This counteracts the notion of a free MOOC and places students unable to pay at a disadvantage. Some publishers may be more understanding (Smith & McDonald, 2013). It is probably best, however, that course authors rely primarily on instructor-generated content or use third-party public domain or open access materials, such as Creative Commons licensed content. Two organizations did grant permission to access and showcase online content specific to geodesign issues, which enabled the course author to provide key information about geodesign that would not have been possible otherwise.

4. OUTCOMES

4.1 Geodesign MOOC Course Design and Structure

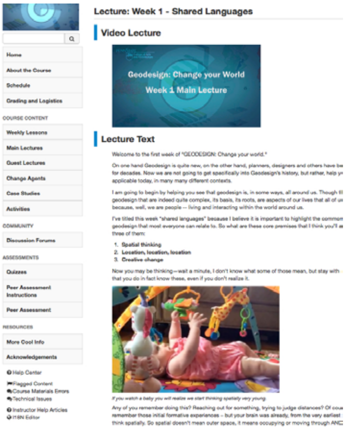
This course was developed by working through a desired set of learning objectives and matching those to logical course content, including outlining seminal introductory-level geodesign topics (Table 1).

GEODESIGN MOOC	TOPIC/SHORT OUTLINE	LEARNING OBJECTIVES
Week 1	Shared Languages (Key underpinnings of geodesign) • Spatial Thinking • Creative Change • Location, location, location	1) Identify how geodesign embodies "things"' that are within vour personal, everyday experience 2) Be able to identify and explain the potential for change in a problem. 3) Begin to explore what geodesign is through interactive mapping (Case Studies) and readings.
Week 2	The Three 01s of Geodesign (Geodesign is a design process) • Design • Decision • Data	1) identify the key components and their operations (or functions) that are central to the geodesign process. 2) Recognize how these three key components are interrelated. 3) Continue to explore what geodesign is through interactive mapping and readings.
Week 3	The Three C's of Geodesign (Geodesign components in action) • Complexity • Computation • Collaboration	1) Recognize the complexities inherent in the geodesign process 2) Be able to explain the value of computation and collaboration to geodesign. 3) Translate week two's components into an understanding of how those are put into action to accomplish geodesign.
Week 4	The Influence of Context (Culture of shaping force) • People of the Place • Factors and Scale	1) Recognize that there are myriad factors that influence how a development may impact upon a place. 2) Be able to describe the value of local knowledge. 3) Gain understanding about the interrelationships of the physical and human aspects that contribute to how geodesign strategies are c.omposed.
Week 5	Process and Framework (The value of using a proven process) Six models as the method to address fundamental questions	1) Build awareness that there is an iterative process needed to work through a geodesign challenge. 2) Distinguish between all the components of the geodesign process and how each one's role contributes to the process. 3) Be able to describe the scope and team members who should participate in a self-selected geodesign study.

Table 1. The learning objectives for each week of the MOOC.

A five-week structure was established and designed for approximately three to five hours of student engagement per week. The course design designates each week as one lesson that centres on a major theme or key topic. The learning objectives and topics were prioritized from a list the faculty course author assembled based on research during preparation of new graduate course proposals, a review of issues from recent conferences (Geodesign

Summits), and as stated previously, the particular perspective this geodesign MOOC intended to cultivate. The design and structure of two recent successful MOOCs at Penn State University were also analysed (www.coursera.org/course/maps, www.coursera.org/course/art).



Welcome to the first week of "GEODESIGN: Change your world."

On one hand Geodesign is quite new, on the other hand, planners, designers and others have be
for decades. Now we are not going to get specifically into Geodesign's history, but rather, help y
applicable today, in many many different contexts.

I am going to begin by helping you see that geodesign is, in some ways, all around us. Though t
geodesign that are indeed quite complex, its basis, its roots, are aspects of our lives that all of u
because, well, we are people -- living and interacting within the world around us.

I've titled this week "shared languages" because I believe it is important to highlight the common
geodesign that most everyone can relate to. So what are these core premises that I think you'll a
three of them:

1. **Spatial thinking**
2. **Location, location, location**
3. **Creative change**

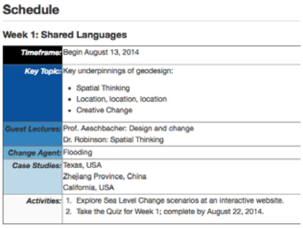
Now you may be thinking—wait a minute, I don't know what some of those mean, but stay with
that you do in fact know these, even if you don't realize it.

If you watch a baby you will realize we start thinking spatially very young.

Any of you remember doing this? Reaching out for something, trying to judge distances? Of cou
remember those initial formative experiences – but your brain was already, from the very earliest
think spatially. So spatial doesn't mean outer space, it means occupying or moving through AN

Figure 3. Example MOOC page shows main lecture displayed as text and graphics.

To address aforementioned issues deemed to enhance MOOC success; the Geodesign MOOC course is designed as modules to offer consistent structure for each week. The MOOC course design team also took the approach that the main lecture video is not the core content; instructional content provided in the other modules is equally valuable. Furthermore, to provide an alternative way to access and view the Key Topic material covered in the video, the lecture content is directly embedded on the Coursera page as text and graphics (Figure 3). Additionally, a companion theme is introduced each week in the form of a "Change Agent". Geodesign is defined as creative change for a place (McElvaney & Foster, 2014). A Change Agent theme is identified to provoke student thinking about who or what instigates change in a place. The structure then for each week includes five modules: A Key Topic, Guest Lectures, Change Agent, Case Study Examples, and Activities. Each module reinforces or complements either the weekly Key Topic or the Change Agent. For example, each guest lecture goes into more detail about a concept revealed in the main lecture's overview of the Key Topic. The Case Study Examples, on the other hand, reinforce each week's Change Agent theme. The weekly structure is announced to the MOOC students as a visually graphic outline, shown in Figure 4. The MOOCs Discussion Forum, which provides a significant means for student engagement, was arranged to include sub-forum discussion areas related to each of the course modules.



Schedule

Week 1: Shared Languages

Timeframe:	Begin August 13, 2014
Key Topic:	Key underpinnings of geodesign: • Spatial Thinking • Location, location, location • Creative Change
Guest Lectures:	Prof. Aeschbacher: Design and change Dr. Robinson: Spatial Thinking
Change Agent:	Flooding
Case Studies:	Texas, USA Zhejiang Province, China California, USA
Activities:	1. Explore Sea Level Change scenarios at an interactive website. 2. Take the Quiz for Week 1; complete by August 22, 2014.

Figure 4. Example schedule showing five modules included in each weekly lesson.

4.2 Geodesign MOOC Subject Matter

Content was selected to respond to the course goals: to create an introductory-level experience, to inspire attitudes about the opportunities geodesign can provide, and to provide a balanced view of what geodesign is, all while being mindful of the platform and "fair use" limitations discussed above. The primary influences on the details of what to include were the Key Topic and Change Agent for each week. These are shown in Table 2. The following provides an overview of the subject matter covered within each of the modules each week.

GEODESIGN MOOC	KEY TOPIC	CHANGE AGENT THEME
Week 1	Shared Languages • Spatial Thinking • Creative Change • Location, location, location	Flooding
Week 2	The Three 01s of Geodesign • Design • Decision • Data	Infrastructure
Week 3	The Three C's of Geodesign • Complexity • Computation • Collaboration	Conversation
Week 4	The Influence of Context • Factors • Scale • People	Sustainable Development
Week 5	Geodesign Process and Framework	Urbanisation

Table 2. The guests provide additional perspective regarding the week's Key Topic.

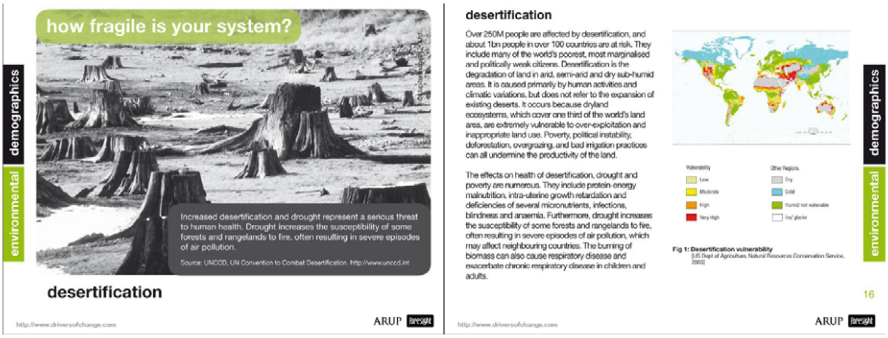
To reinforce that the main lecture video is not the sole source of information, guest speakers were selected to provide additional voices, perspective and expertise on the Key Topic each week. The guest lecturer page in the MOOC provides a short biography about each speaker, but unfortunately the video lecture content is not transcribed. Most of the videos are however captioned, offering students the opportunity to read a transcript during the video. Future offerings of the MOOC hope to rectify this accessibility limitation. The topics covered by the guest lecturers are included in Table 3.

There are of course thousands of reasons change can happen in a place. Change Agents can be forces for positive as well as problematic change. The five Change Agents were selected due to their universal applicability across the global and their representation of how to address both positive and problematic influences in land planning and design contexts. The global design and engineering firm, Arup, has published a series of "cards" called "Drivers of Change" (Arup Foresight, n.d.).

GEODESIGN MOOC	KEY TOPIC	GUEST LECTURER/TOPIC
Week 1	Shared Languages •Spatial Thinking •Creative Change •Location, location, location	Prof. Aeschbacher: Design and change Dr. Robinson: Spatial Thinking
Week 2	The Three 01s of Geodesign •Design •Decision •Data	Prof. Foster: Decision is driver Prof. Aeschbacher: Design: teamwork and iteration
Week 3	The Three C's of Geodesign ••Complexity •Computation •Collaboration	Dr. Flaxman: Tour of geodesign tools Dr. Robinson: Analyzing Data Prof. Aeschbacher: Collaboration
Week 4	The Influence of Context •Factors •Scale •People	Dr. Lisa McElvaney: Human Dynamics Dr. Anthony Robinson: Influence of Scale
Week 5	Geodesign Process and Framework	Or. Olson: Geodesign -Forest Lawn Creek Example Mr. Palavido & Mr. Bhargava: Using GeoDesign Analysis for Sustainable Design and Planning Mr. Beck: Envisioning Utah -Meadowbrook Station Project

Table 3. The guests provide additional perspective regarding the week's Key Topic.

Permission was granted to include a selection of cards chosen for their relevance to weekly Change Agent topics. Figure 5 shows one example card, which is two sided and provides a concise overview on an issue, thus serving as a unique, graphically engaging way to provoke dialogue at an introductory level.



Increased desertification and drought represent a serious threat to human health. Drought increases the susceptibility of some forests and rangelands to fire, often resulting in severe episodes of air pollution.

Source: UNCCD, UN Convention to Combat Desertification. http://www.unccd.int

desertification

http://www.driversofchange.com

ARUP foresight

desertification

Over 250M people are affected by desertification, and about 1bn people in over 100 countries are at risk. They include many of the world's poorest, most marginalised and politically weak citizens. Desertification is the degradation of land in arid, semi-arid and dry sub-humid areas. It is caused primarily by human activities and climatic variations, but does not refer to the expansion of existing deserts. It occurs because dryland ecosystems, which cover one third of the world's land area, are extremely vulnerable to over-exploitation and inappropriate land use. Poverty, political instability, deforestation, overgrazing, and bad irrigation practices can all undermine the productivity of the land.

The effects on health of desertification, drought and poverty are numerous. They include protein-energy malnutrition, intra-uterine growth retardation and deficiencies of several micronutrients, infections, blindness and anaemia. Furthermore, drought increases the susceptibility of some forests and rangelands to fire, often resulting in severe episodes of air pollution, which may affect neighbouring countries. The burning of biomass can also cause respiratory disease and exacerbate chronic respiratory disease in children and adults.

Fig 1: Desertification vulnerability
[US Dept of Agriculture, Natural Resources Conservation Service, 2003]

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http://www.driversofchange.com

ARUP foresight

Figure 5: Example Change Agent "card" addresses Week 3 theme: Conservation (Arup Foresight, n.d.).

Showcasing real-world examples of what geodesign is and can be was deemed an essential component of the MOOC. Case study examples were curated to reinforce each week's Change Agent topic (Table 4).

GEODESIGN MOOC	CHANGE AGENT THEME	CASE STUDY EXAMPLES: TOPIC AND LOCATION
Week 1	Flooding	• New National Recreation Area on the Gulf of Mexico: Texas, USA • Growth Pattern of Taizhou City Based on Water Network Landscape: Zhejiang Province, China • Napa River Flood Protection and Waterfront Redevelopment: California, USA
Week 2	Infrastructure	• Exploring options for shale gas pipeline and roadway development: Pennsylvania, USA • Designing for expansion of a national electricity network: Spain • Retrofit five-lane arterial into walkable townscape boulevard: Arkansas, USA
Week 3	Conversation	• Model for heritage conservation of a significant cultural landscape: Shandong Province, China • Halting River Delta decline to protect livelihoods and natural resources: Louisiana, USA • Uncovering buried stream creates ecological, recreational and economic opportunities: Seoul, South Korea
Week 4	Sustainable Development	• Working to reduce carbon emissions in small towns: British Columbia, Canada • Land-based strategies rooted in natural terrain that affordably promote development: Rwanda, Africa • Transform brownfield into living filter to create habitat and enhance public health: Zhejiang Province, China
Week 5	Urbanisation	• Partnerships foster cooperation to design transit-oriented centers: Utah, USA • Port transformed into sustainable communities that respect unique heritage: Hamburg, Germany • Flooding challenges to historic town require both offensive and defensive strategies: Colorado, USA

Table 4. Case Study Examples chosen to illustrate the weekly Change Agent Theme.

Fifteen case studies were chosen, over half of which are outside the USA and representing seven countries. It was a distinct challenge to find the desired level of detail available for access solely online. These illustrative case studies were interactively mapped via Esri's Story Maps (http://storymaps.arcgis.com), and each case study example includes web links for further explanations (Figure 6). To facilitate accessibility each case study example was also provided as a PDF. Permission was granted for these, the most prominent of which is the American Society of Landscape Architects's extensive website for award winning projects (ASLA, n.d.).

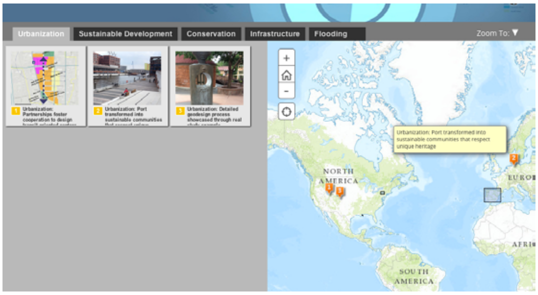


Figure 6. Case Study Examples illustrated via a dynamic interactive map. Each tab represents a Change Agent Theme.

The activities each week included readings and an interactive activity that relates to either the Change Agent or Key Topic. These were designed to address the aforementioned issues of student engagement and knowledge application. The students' final activity is a peer-assessed assignment; they were asked to outline a geodesign challenge upon what they've learned. This final assignment reinforces the goal of having the course be relevant to the students and to help them understand positive change possibilities for their area of interest. The assignment requires the student to discuss seven items, six of which tie directly to the MOOC's weekly topics: what type of change (select from the Change Agent-types); describe why creative change is needed to address the challenge; what scale is most appropriate; who should be the collaborators; what factors will impact the situation; and what types of data are needed. The seventh item is a website address that provides background about the geodesign challenge. Students submitted a short PDF addressing those seven items and also 'pinned' their challenge location to a class map. Figure 7 shows the mapped final assignments, with each colour representing a different type of Change Agent.

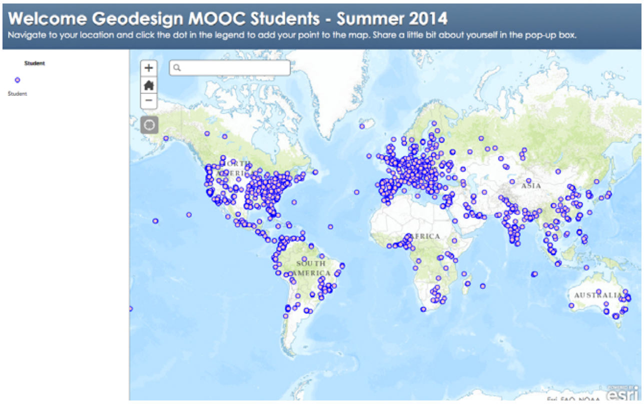

MOOC: Final Activity - Geodesign Challenges

hange Agent. Go to Challenge location to drop your pin. Add brief summary.

Figure 7. Students' final assignment outlined a Geodesign Challenge. The location of each challenge is mapped with the "pin" colour selected to signify the challenge's Change Agent category.

4.3 Student engagement

The Coursera platform has several analytic tools to measure the reach and level of engagement in the course. The Geodesign MOOC enrolled nearly 17,600 students, representing 167 countries. This is in line with a typical MOOC enrolment size of 20,000 (Jordan, n.d.). Of those registered, 38% are considered to be from emerging economies. The course attracted at least one visit from 10,368 or 59%, and 7,890 or 45% watched at least one lecture. For the first time offering this MOOC, the team is happy to see the goal of beginning to build wider awareness of geodesign met with some success. Taking the nearly 8,000 as the 'maximum' engagement via videos, the analytics reveal that 20% of that number were still active in the last week by viewing the main lecture video. Because of the platform limitations and Coursera's emphasis on video content, we unfortunately cannot easily get statics on visits to, for example, the Case Study Examples pages.


Welcome Geodesign MOOC Students - Summer 2014

Navigate to your location and click the dot in the legend to add your point to the map. Share a little bit about yourself in the pop-up box.

Figure 8. Students' final assignment outlined a Geodesign Challenge. The location of each challenge is mapped with the "pin" colour selected to signify the challenge's Change Agent category.

Familiarity with the Penn State University Maps MOOC enabled the Geodesign MOOC team to deploy a best practice for early student engagement, a class map (Figure 8), which was available beginning the week from before the MOOC opened (Robinson et al., 2015). Students self-locate and share a little bit about themselves, thereby enabling all students to experience a common connection with their peers.

As discussed above, the primary place for student engagement in MOOCs is the discussion forums. Due to the large volume of posts, these can be difficult to monitor closely. Awarding participation points for merely submitting a post to a forum was deemed too superficial, as our MOOC team has no easy way to monitor content. To stimulate student participation, points were awarded if a discussion post receives 'up votes' from fellow MOOC participants. This empowers each student to weigh in on the relevancy or significance of a post, as well as encouraging students to compose thoughtful posts. One student received 32 up-votes over the course of the five weeks, and nearly 150 students received at least one up-vote on a forum post. There were a total of 2,228 forum posts, but well over 23,600 forum-post views. The difference between views and number of posts seems to validate the previous discussion that some MOOC students are primarily there to look at content and browse course resources, which de Waard et al. (2011) called the "lurking participant".

The final peer-assessed assignment served as the other primary avenue for student engagement. Using 7,890 as maximum participation (watched at least one video), the analytics show that 482 or 6% participated in the final assignment. Of those, 451 (5.7%) satisfactorily completed all the MOOC course requirements to earn a statement of accomplishment. These numbers fall within the overall completion rates experienced by other MOOCs (Jordan, n.d.).

The Geodesign MOOC was designed for three to five hours of engagement per week. A post-course survey administered by the Geodesign MOOC team reveals that most of the students hit that target: 35% selected one to three hours, and 48% chose three to six hours per week.

4.4 Student Feedback

There were two post-MOOC surveys aimed at better understanding student reaction to the course: both Coursera and the Geodesign MOOC team requested student feedback. One caveat: there is no way of knowing to what extent participation in these surveys overlap, however there is enough distinction in questions to use both. Though these received relatively low participation rates (Coursera, 1.8%; MOOC team, 2.7%), the feedback is none-theless helpful.

Related to the above discussion about hours of engagement per week, 74% of the students felt the course pace was "just right", while 21% felt is was "somewhat fast". There are several questions regarding the course design. A solid majority rated the quality of the course materials as "excellent" (48%) and "Good" (47%). The question "how relevant do you think the exercises (e.g. quizzes, assignments) are to the rest of the course?" also yielded positive feedback: 50% at "very relevant", 26% at extremely relevant". The responses to the next question point to needs in student engagement improvement: "how valuable are the discussion forums … in helping you learn?" 39% said "moderately valuable", while the same percentage (22%) said "very valuable"/"slightly valuable", and 7% said "not at all".

The Geodesign MOOC team is particularly pleased to see the student's self-assessed learning metric that provides insight into our goal of improving understanding about geodesign, with over 50% stating "quite a lot". Additionally, 28 students provided a personalized written response to Coursera's open-ended "Learner Stories", which ask students to share course experiences directly to the MOOC instructor. These were wonderful comments to read and came from an astonishing amount of eighteen different countries, ranging from Brazil and Venezuela, to India and Thailand, to Saudi Arabia and the UAE, to Morocco and Democratic Republic of Congo, to five European countries and the United Kingdom, and the USA. These students reported seeing both specific and broad applicability of the geodesign concepts.

5. CONCLUSION

This contribution has described the background, course design and content details associated with offering the first MOOC on the subject of geodesign. The author has also provided an overview of pedagogical and technical considerations found to be associated with producing a successful MOOC. Based on this work several challenges and opportunities emerge.

The faculty course author struggled with how best to balance representation of a process as complex as geodesign without oversimplifying it. The results show that nearly a quarter of the participants felt the pace was a bit too fast. This dilemma of how to best address different learning abilities and levels of prior knowledge is shared with resident instruction, but is likely more pronounced in MOOCs because there are no course entrance standards. Techniques need to be researched and developed for how to engage this wide-range of users without overwhelming some.

Another challenge is how to resolve the conflict between research showing students desire to apply newly learned knowledge and the low percentage of students who participated in the assignment that does this best. There appears to be a need to seek other, less intensive ways that enable students to apply knowledge while still being meaningful.

Student engagement issues related to the discussion forums appear to point out an opportunity to enhance student interaction. Helpful alternative forum engagement strategies, such as those discussed in Robinson et al. (2015), can be investigated. A future modification could include the course instructor selecting and "elevating" insightful or helpful forum posts to bring these to the attention of all MOOC students, and posing further questions or discussion prompts related to these.

The faculty course author's self-reflection reveals an admittedly surprising sense of connection to these students and an overall feeling of success in achieving the course goals. Although there are thousands, those students that chose to share and engage expressed a depth of interest in geodesign not anticipated. And even those that did not share, the fact that thousands watch a video reveals a unique reach well-beyond typical teaching experiences. It was also enlightening to see the diversity of truly inspiring geodesign challenges identified by the students. The students clearly have issues and concerns in their locales for which they see geodesign as a possible way forward. The ability to reach so many individuals across the globe is both humbling and exhilarating. This all reinforces the magnitude of responsibility to prepare a first-rate experience for the students.

The MOOC format is shown to have great potential for informal and lifelong learning. MOOCs also have the amazing capacity to reach individuals from around the globe. Making use of this unique format for introductory exposure to topics should continue to prove valuable as the desire to reach more audiences and the need to increase exposure to geodesign grows. The survey data and student feedback support utilizing a MOOC to build awareness and disseminate information about geodesign. Due to geodesign's complexity, there are certainly possibilities for taking any of the weekly topics and, for example, expounding on those to create five or more MOOCs, each delving into more detail about those components of geodesign. There is clearly interest, worldwide, and due to the interdisciplinary nature of geodesign, as well as the diversity of scales and issues geodesign can address, it is the author's opinion that there is abundant opportunity for more to get involved in expanding the dialogue about geodesign.

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Creating a Geodesign syllabus for Landscape Architecture in Denmark

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Abstract

Geodesign provides a conceptual framework through which to understand relationships between geoscience and design. This paper takes its point of departure from the merger of the Departments of Geography and Geology and Forest, Landscape and Planning at the University of Copenhagen, and the subsequent approach taken to Geodesign as a means to realise potentials within the new academic structure. The aim is to address specifically how an on-going process of transforming the Landscape Architecture program has begun to integrate GIScience in a new way that fosters integration within and between disciplines. The approach to Geodesign will therefore be discussed in terms of cross-disciplinary dialogue and curriculum development. Emphasis will be placed on the results of the Geodesign Conference held at UCPH in November 2014 at which practitioners and academics came together to present extensive experiences and understandings of Geodesign. The conference was also the forum for discussion of the challenges and opportunities offered by Geodesign in the context of teaching.

KEYWORDS

Geodesign; GIScience; Landscape Architecture; BSc education; University of Copenhagen

1. INTRODUCTION

During the European Geodesign Summit 2014 at TU Delft it became clear that, while the number of Geodesign oriented programmes and courses is increasing in the U.S.A, use of the term Geodesign at European universities was only just beginning. In this context the work of the University of Copenhagen (UCPH) with Geodesign must be seen as somewhat pioneering and exploratory. This chapter presents the first concrete initiatives of the newly formed Department of Geosciences and Natural Resource Management (IGN) aimed at harnessing the potential of Geodesign. These initiatives include the Geodesign Conference in Copenhagen 2014 (Geodesign Conference, 2014) and the current transformation of the BSc program in Landscape Architecture at UCPH.

This paper explores the background and profile of the BSc program in Landscape Architecture at the UCPH, and the development of GIS education in Denmark generally. The unusual coupling of academic disciplines at IGN is explained with the significant potential that it offers for interdisciplinary work. The field of Landscape Architecture education is ever evolving as the nature of landscape problems and opportunities change over time. The means by which we teach, learn and do landscape architecture are equally evolutionary and the pace of that evolution is ever quickening. The means to tackle complexity through the use of IT, for example, have multiplied remarkably in recent years. The consequences of these rapid developments can be hard for even experienced teachers and practitioners to comprehend, and frameworks within which to understand these changes are essential. Geodesign is one such framework, offering a conceptual model that can cross disciplines, but it aims consistently at facilitating and understanding spatial change.

Geodesign brings into focus a range of methods and tools that many Landscape Architecture educational programs are already using, but significantly Geodesign makes communication with other disciplines, and practices possible in new ways. Importantly, Tom Fisher (2010, 2014) identifies a key strength of Geodesign as that of critically addressing the consequences and impacts of proposals. He states that traditional design thinking focuses too much on the current and immediate needs of the clients and communities. By addressing the impact of design and planning decisions practitioners are forced to adopt a descriptive stance before returning to a reformulation of their otherwise prescriptive work. The tools and methods necessary for this shift give a common platform of understanding with scientific disciplines where the prescriptive nature of planning and design is often viewed with scepticism.

As a relatively new and evolving term Geodesign is still at an early, formative stage, and questions of how to organize and structure Geodesign education, its curriculum, scope and workflows are being explored by an increasing number of academic institutions that are adopting Geodesign within existing programs, or establishing new majors with Geodesign at their core (Paradis, Treml, & Manone, 2013). The relationship of Geodesign to well established disciplines such as Landscape Architecture and Geography remains a focus for a number of academic papers, and almost all summits and conferences organized to date.

Carl Steinitz (2013) in his speech given at the Geodesign Summit 2013 in Redlands, CA, presented options for organizing educational institutions and programs based fully or partially on Geodesign. Steinitz shared his opinion that a design profession school should combine several design oriented disciplines, e.g. architecture, landscape architecture, urban planning. Similarly to Fisher (2014), Steinitz argues that 'even the school of design [...] does not have all the things that influence it and it influences'. To his mind a favourable situation (also with great Geodesign potential) is when such design school is coupled with geographical sciences. At UCPH the ambition of combining Landscape Architecture, Planning and Geosciences presents itself as achievable due to the unique disciplinary organisation of the university.

2. BACKGROUND

2.1 Organizational change at the University of Copenhagen

The Department of Geosciences and Natural Resource Management (IGN) at the UCPH was formed in 2013 after a series of mergers, and reorganisation of research and university institutions.

Starting in 1991 a Department of Economy and Natural Resources (ENR) was formed at the Royal Veterinary and Agricultural University of Denmark (KVL) by the merger of the small institutes of Landscape Architecture, Urban and Rural Planning plus Forestry, and Applied Economics. In 1992 a number of Danish technical and applied research organizations in forestry and landscape engineering were merged to form the Danish Forest & Landscape Research Institute (DFLRI) under the Ministry of Environment. Later in 1996 physical and urban planning, as well as GIS were added to the institute's research profile. In the late 90's most ministerial research institutions in Denmark were transferred to universities. Therefore, DFLRI was merged with ENR to form a new department of Forestry, Landscape and Planning at KVL. In 2007, KVL was merged with the UCPH. However, the organisation of KVL remained intact as a Faculty of Life Sciences (LIFE). In 2013 a new faculty of Science was formed merging parts of LIFE with the UCPH Faculty of Natural Science. From the latter the Institute of Geography and Geology was merged with the largest part of Forestry, Landscape and Planning to form the IGN. It is now a rather large university department with approximately 450 FTEs (including 160 enrolled PhD students) and 2000 students.

A result of these mergers has been the creation of a significant concentration of GIS expertise in both teaching and research at the department. This expertise is found across all five sections of IGN: Forest, Nature and Biomass; Geography; Geology; Landscape Architecture and Planning; and the Forestry College. With a range of theoretical and methodological traditions these sections are all engaged in understanding, predicting, planning and managing the spatial domain of human environmental interaction.

According to the IGN departmental strategy, formulated in the spring of 2013, the merger of diverse departments resulted in "an increasing need for internal cross-program collaboration. In the fields of geography, nature management and landscape architecture, new possibilities should be identified, assessed and pursued, both to ensure efficient use of resources and to develop new potential" (IGN, 2013).

In this context, Geodesign has been seen as a promising framework within which to conceptualize key activities at IGN. Geodesign would also appear to offer significant opportunities to promote integration and cross-disciplinary collaboration between the scientific domains already present at IGN, in particular between the sections of Geography and Landscape Architecture and Planning, but also other fields working with Hydrology, Forestry, Climate Adaptation, Recreational Planning, Urban Livelihood and Mobility, and Nature Management. Therefore, IGN has chosen to foster Geodesign both in terms of research and teaching.

2.2 Landscape Architecture at the University of Copenhagen

The current BSc and MSc educations in Landscape Architecture at the UCPH have developed from Garden Architecture teaching at the then KVL in the 1930's. Later in the 1960's a specific Landscape Construction education gave rise to what has become Denmark's largest Landscape Architecture education. By 2000, a strong research tradition was developing in connection with the education and in 2002 a new research and teaching department was formed named Forest, Landscape and Planning. In 2006, the landscape architecture BSc increased student uptake and since then, has offered a specialization in Physical Planning, now at both BSc and MSc level. In the same period, teaching of all masters programs switched to teaching in English and the number of non-Danish students and staff increased rapidly. Specifically, Urban Forestry as a subject area fed an interest in Urban Greenspace Planning and Management, and now the MSc offers specialisations in Landscape Design, Urban Planning, and Greenspace Management. The growth of Landscape Architecture as an academic endeavour is reflected in a burgeoning PhD cohort, and a steady increase in professorships.

Teaching within Landscape Architecture at UCPH is science-based with the clear sense of design and planning as the interplay of art and science. On the BSc level students are schooled in natural processes in parallel with the development of an aesthetic sensibility fostered through creativity. Plant, soil science, and water management are, for example, taught through 'learning by drawing' techniques, and early design projects address challenges that have clearly defined scientific and aesthetic aspects.

The history and current practice of Danish landscape architecture, architecture and planning is drawn on extensively in teaching. This, and the students' a priori awareness of the Danish design tradition, contributes to a generally significant aesthetic sensibility amongst students. The vibrant educational environments associated with other Danish design and architecture schools in Copenhagen also feed into this. In this context, the aim is to negotiate means for engagement with aesthetics, through design, in relation to natural science and human processes. Since the expansion of the Landscape Architecture programs into urban planning, the role of design and aesthetics within the discipline has presented new challenges. Not least, because many colleagues from beyond the design disciplines are engaged in teaching on the programs. At the same time a growing number of designers have joined the existing staff, and research in design processes at UCPH has been fruitful in recent years. This has been reflected in the teaching in relation to design process and in particular the use of IT. However, the latter has been somewhat fragmented and has had a limited reach amongst teaching staff. Within the Department the research group for Landscape Architecture and Urbanism has taught the BSc course Design Method and IT tools (AutoCAD and Adobe), and the MSc course Terrain and Technology in Landscape Architecture (Civil3D). GIS has been taught from outside this group and has been only weakly integrated into the BSc and MSc programs.

2.3 GIS practice and education in Denmark

GIS is well embedded within various educational programs in Denmark and a thriving GIS-user community exists both amongst academics and practitioners. Computer based mapping and handling geographic information emerged in Denmark in the 70's and 80's with projects relating to utilities (Jacobi, 2006), agricultural land-use mapping (Platou, 1984) and geological mapping (Jørgensen, Hermansen, & Jensen, 1993). Early development of in-house systems failed to reach a level of maturity, but served to establish the professional discipline and highlighted the need for development, research and education.

In the early 90's a range of universities and other educational institutions, mainly in disciplines relating to architecture, engineering, and geography, became active within the field. In particular Aalborg University, the Institute of Geography of the UCPH and the Institute of Landscape at KVL. In 1991 UGIS, a consortium of academics from various universities, was formed (Balstrøm, 1992). The intention was to coordinate teaching and research, and to exchange experiences and knowledge within the fairly modest number of researchers interested in GIS at the time. UGIS resulted in an enhanced national network and a range of book- and inter-university teaching activities (e.g. Balstrøm, Jacobi, & Sørensen, 1992, 1999). Despite its obvious need, the organization did not sustain. The main reason was that universities due to politically motivated reforms were encouraged to compete regarding fund and students.

At present GIS is taught at several Danish universities. At Aalborg University, Roskilde University, and the UCPH undergraduate education is provided, whereas numerous courses aiming more or less explicitly at geoinformatics are provided by Aarhus University, the University of Southern Denmark, and the Danish Technical University.

In a Global context explicit considerations regarding application of GIS and other geo-focused technologies to planning range back to the mid-90's (e.g. Batty, 1995). Planning Support Systems (PSS) and Spatial Decision Support Systems (SDSS) have developed to be common terms for "models and methods that inform the planning process though analysis, prediction and prescription [and] provides the driving force for modelling and design" (Geertman & Stillwell, 2009). Traditionally these approaches have been particularly aimed at registration and ex-ante description of the present, and the processes leading to it. Geodesign is in addition concerned with ideas and suggestions of what the future could be to cater for observed or foreseen problems or to afford future needs and wishes. Accordingly, Geodesign adds informed creativity, means/tools for developing/expressing proposals, and ex-post evaluation of potential effects and functionality of proposed designs to assessments of the past/present made by GIS (and SDSS).

In May 2009 national law was enforced as an implementation of the EU's INSPIRE directive (Denmark, 2014; INSPIRE, 2014). The law states that a range of geodata, services and metadata repositories, including data produced by municipal and state authorities, must be made publicly available (Danish Geodata Agency, 2014a). Among the many very good things about such open access is that teaching and education relating to geodata can take place on the same data as applied in real-world by private and public organizations.

2.4 The formation of the GIScience & Geodesign research group

With the creation of IGN in 2013 the newly formed Section for Landscape Architecture and Planning restructured its research groups. A new GIScience & Geodesign group was formed, aiming to bring together researchers and teachers within the section, and across IGN, working with GIS in interface with other software. The group offers the benefits of coordinating the teaching of computer based spatial analysis and design, but it also requires a broader perspective, one that is not bound to the use of specific software.

According to Steven Ervin it is probable in the future of Geodesign that "we will no longer need to distinguish between building and landscape, or CAD, or GIS, or BIM [Building Information Modelling], or LIM [Landscape Information Modelling]" (Ervin, 2012). This understanding of the evolutionary nature of IT processes is seen as essential within the group. The group is engaged in comprehending and problematizing the application of IT to spatial problems, requiring dialogue and a broad understanding of the possibilities for analysis, planning, and design processes across IGN.

3. AN APPROACH TO GEODESIGN

Geodesign is seen as a set of tools and methods founded in iterative, explorative and creative design processes. These processes are under constant development as they are challenged, expanded and transformed by the increasing availability, and expanding functionality, of geo-spatial technologies and data management systems. At UCPH unique opportunities for collaboration across Geo-disciplines create a strong platform from which the aim is to help drive these developments.

The task of bridging science and design involves the development of methodologies that harness the power of analysis offered by digital data as a means to open up and expand the possibilities for speculative and exploratory planning and design. For geo-scientists the challenge is to understand the open-ended nature of design processes, while for designers the challenge is to understand the depth and significance of geo-data and geo-data processing.

The first phase of this interdisciplinary approach has brought Geographers, GIS professionals, Landscape Architects and Designers together to begin teaching Geodesign on the Landscape Architecture program. Now the potential to broaden the scope of Geodesign teaching to engage multidisciplinary student groups, in and beyond the Landscape Architecture curriculum, is seen as an all-important next challenge.

3.1 The Geodesign Conference in Copenhagen 2014

To kick-off the venture into Geodesign at UCPH it was decided to arrange a one-day conference with invited international speakers at the forefront of Geodesign teaching and practice. The Geodesign Conference in Copenhagen was held on November 11th 2014 with around 110 attendees (Geodesign Conference, 2014). These ranged from practitioners from private and public sectors, bachelor, master and PhD students, and faculty and management from the department. The morning session of the conference was devoted to mapping the concept of Geodesign with the focus on background and technologies. The afternoon session focused on curriculum development and establishing Geodesign education and training.

In connection with the conference IGN hosted what we believed to be the first Geodesign PhD course in Europe. For attendees of the course, their first day involved attending Geodesign conference, helping to frame the concept and put it in perspective. The following days were dedicated to presentations by selected invitees and PhD students' own projects. These presentations and discussion sessions were held in an informal manner where ideas were exchanged freely. The detailed list of speakers and topics discussed during the conference and PhD course can be found in Table 1. Videos of the presentations can be found via the Geodesign Conference in Copenhagen homepage (Geodesign Conference, 2014).

SPEAKER	SPEECH TITLE	CREDENTIALS AND AFFILIATION
	Morning session	
Thomas Fisher	The rationale, definition and history of Geodesign	Professor and Dean of the College of Design, University of Minnesota
Michael Flaxman	a) Geodesign in Environmental and Regional Planning Practice b) Applying Geodesign thinking to ongoing and advanced projects within various disciplines	CEO at Geodesign Technologies, former Associate Professor at Massachusetts Institute of Technology
Elliot Hartley	State of the art and pointers to the future of Geodesign technologies	Director at Garsdale Design Limited
	Afternoon session	
Stephen Ervin	a) The making of a Geodesign proponent: A Systems View and Personal Journey; b) A Geodesign syllabus for Landscape Architecture and Urban Design c) Geodesign as a research area and academic discipline	Assistant Dean for Information Technology, Harvard Design School, Director of Computer Resources, and lecturer at the Department of Landscape Architecture, Harvard Graduate School of Design
James Querry	a) Transforming a classic landscape architectural education to Geodesign b) A Geodesign syllabus for landscape architecture and urban design developed at Philadelphia University.	Associate Professor and Director of the MSc. in Geodesign Program at The College of Architecture and the Built Environment at Philadelphia University

Table 1. Conference speakers and presentations.

4. IMPLEMENTING GEODESIGN IN THE LANDSCAPE ARCHITECTURE CURRICULUM

As of September 2015 the BSc program in Landscape architecture at IGN adopted a simplified structure with an emphasis on clearer progression and alignment. Geodesign methods and concepts play a key role in these developments, helping to bridge diverse disciplines and approaches. Geodata and related IT tools are introduced in the context of design and planning methodologies with increasing frequency and intensity through the curriculum.

Methods and topics will be revisited iteratively, building to allow students to tackle ever-increasing complexity in problem solving. Understanding of design processes will be closely coupled to assessment of design tools and their relevant application. Geodesign will act as a clearly defined way marker for a ‘spiral syllabus’ (Bruner, 1960) and play the key role in initiating this form of learning. The introduction of powerful IT offers a relevant impetus for such reflection.

To build the foundations of work with Landscape Architecture the first year of the program focuses on natural and human processes, creative expression and aesthetic sensibility using simple-to-use technologies and methods. At this stage, the tracks will be laid for the development of Geodesign with the introduction of key concepts. A start will be made in design work including an introduction to design frameworks (Steinitz, 2012). Teaching on the first year will include the simple use of online GIS map data, both commercial and from public bodies, specifically online repositories of planning-relevant data. Apps that students already use or can quickly become proficient in offer other easy means to ‘lay the tracks’. For example Blenduko in color theory teaching and Minecraft in perspective teaching are already being used.

Other applications which the students are familiar with, e.g. Google Maps or the Danish Planning System (Danish Planning System, 2014), including The Danish Natural Environment Portal (Danmarks Miljøportal, 2015) and Historic Atlas (Historisk Atlas, 2015), provide a basis for the discussion of geo-technology in relation to design methods.

The second year is explicitly Geodesign-focused with tools such as GIS and CAD being introduced. Here data capturing, storage, analysis and presentation are combined with design projects, and 3D visualizations are developed.

The third year, where students specialize in either landscape design or urban planning, there is scope for steady development of Geodesign skills and the bachelor thesis offers the opportunity for students to demonstrate their proficiency in the use of tools and methods. By this stage in the education, the aim is to identify the extent to which Geodesign thinking informs the students’ approach to their work (Table 2).

4.1 The Geodesign studio

As part of the new curriculum in September 2015 a new Geodesign course was introduced in the three year Bachelor program in Landscape Architecture. The course runs halftime throughout the first semester of the second year with 58 students enrolled. It is a studio course where introductions to geo-data, GIS and CAD inform analysis and design methodologies. Students combine a number of methodologies dependent on task, complexity and landscape scale. The study area in 2015 was the municipality of Greve, south of Copenhagen where, in response to periodic flooding, local planners have taken a strategic regional approach that has required numerous local landscape-based solutions. Students have analysed this regional situation and planning framework as the context for their own landscape interventions. A site was selected based on situation, accessibility for students and the potential for rewarding landscape design. The site is a shallow valley covering 35 hectares of ex-agricultural land attached to an old agricultural school. The small stream Odsbækken runs through the valley and down into the urban areas of Greve where flooding has been common.

YEAR	SEMESTER 1		SEMESTER 2
1.	Plan & Design 1: Studio		Plan & Design 2: Studio
	Natural Processes 1		Natural Processes 2
2.	Geodesign: Studio		Elective courses
	Botany	Philosophy of Science	
3.	Plants & Technology 1: Studio	Plants & Technology 2: Studio	Bachelor Project and Bachelor Internship
	or		
	Urban Design 1: Studio	Urban Design 2: Studio	

Table 2. Outline of the Landscape Architecture BSc curriculum.

4.2 Teaching approach

The main focus of the teaching approach is to ensure that the development of technological craftsmanship and structured scientific argumentation and working methods can fuel qualitative creative thinking and ultimately ignite the imagination. Likewise domain specific methodologies and knowledge, inferential analytical approaches and insight into the characteristics of existing geo-data are essential components to be tackled with creative sensibility, perception and speculation. This was tackled through a series of design workshops.

Site visits have been structured to give students an unfolding understanding of both the hydrological region and the locality. By visiting the site early, before doing instructional GIS and geo-data exercises in computer laboratories on campus, students could put a landscape to the geo-data they would be handling subsequently. A second visit allowed students to correlate their perceptions and understanding of site in the light of both geo-data and their own first site-design concepts.

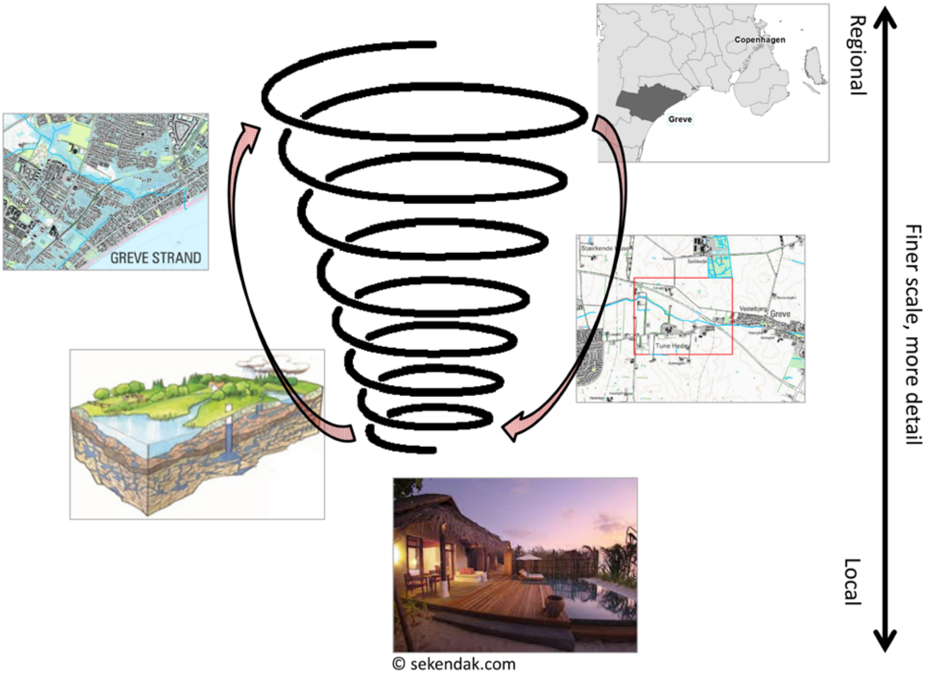

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Figure 1. A spiral approach to teaching Geodesign. See the text for details.

4.3 Spiral teaching

The concept of spiral teaching (Bruner, 1960; Harden & Stamper, 1999), as applied in the present context, manifests itself through the visiting and revisiting of the same location at different geographical scales, assessing different planning and design themes and perspectives, and applying different mediations – quantitative and qualitative, digital and analogue etc. As illustrated in Figure 1, the point of departure is the region of the target area moving down towards the target area at a local scale. A core point of the spiral approach to teaching is that it is not unidirectional, i.e. approaches do not only go from coarse to fine scale. The phenomena at hand can, and should, be revisited iteratively during the design process. An example could be evaluation of more or less detailed design proposals in their immediate surroundings (e.g. assessment of visibility of designed objects) or within a larger region – for instance water retention capacity of proposed designs relative to the potential water volumes of the entire watershed.

Similarly thematic 're-visiting' is part of the spiral. For instance when a design for water retention is proposed, the potential accessibility for local recreational activities could be tested.

5. DISCUSSION

With these early initiatives at UCPH to promote the concept of a Geodesign framework, experience has been generally positive. The approach to addressing Geodesign has been broad in its reach, both through the projected changes to teaching, which engages many teaching staff directly, and through the conference format and the communication related to that. This breadth is considered important in terms of establishing Geodesign. From being an initially opaque and elusive concept for most colleagues an understanding of Geodesign as a useful framing concept has been widely taken up. Geodesign has by definition so many points of contact with other disciplines that it has proved remarkably easy to engage colleagues from across IGN in a common discussion.

It is fair to say that from across disciplines it seems easy for individuals to see themselves in relation to Geodesign and this is particularly interesting in the case of declared non-designers. The common use and understanding of GIS and other land-based tools is perhaps the key to this.

One consequence of the newness of Geodesign can be seen in the disappointing attendance at the PhD course. Despite intensive advertising through social media and professional networks only four students attended. This and experiences shared by Fisher and Querry leads to the conclusion that, at least for now, Geodesign workshops and courses should aim at supporting specific disciplines and/or address specific issues.

This relates to a discussion of the extent to which Geodesign should be considered a distinct discipline itself that might warrant a separate program of study. At the conference it was explained how Philadelphia University has established a specific Geodesign focused major, while quite consciously the University of Minnesota has implemented Geodesign teaching only within the existing curriculum. A concern raised by the Faculty at UCPH has been that as a stand-alone practice Geodesign could develop as an isolated quantitative and computational activity without the ballast of the strong design tradition of, say, Landscape Architecture. A consensus seems to exist around the idea that Geodesign should function within and across existing disciplines and that Geodesign should not at this stage be regarded as a distinct discipline. This may change, but for now there seems to be no expectation that the institution will be educating ‘Geodesigners’. The potential for cross-disciplinary collaborations with their starting point in Geodesign is clear. Tackling Geodesign through existing programs and courses offers the opportunity to reach a range of disciplines and explore what Geodesign means for a range of practices. The situation at IGN seems to offer a promising test-bed for Geodesign. There is also a clear sense that Geodesign in this context will develop differently from Geodesign at other institutions.

6. FUTURE EDUCATIONAL AND RESEARCH PERSPECTIVES

With a strong tradition of cooperation with practice at the UCPH the relevance and practicability of Geodesign tools will be regularly re-evaluated in that context. However, the specifically pedagogical potential of Geodesign thinking is also essential to success in teaching and this will not coincide with the requirements of practice 100%. This potential lack of congruence between tools for practice and tools for teaching and research will be explicitly addressed in future developments of Geodesign in Copenhagen.

With Geodesign entering the BSc curriculum in 2015, for year-two students, there will be a relatively rapid uptake of Geodesign tools amongst the students. This will mean that in 2017 the intake to the MSc will be dominated by students with grounding in Geodesign, and here courses will be able to take advantage of students' skills. It will also be relevant to look at the potential for advanced Geodesign courses at this level.

The opportunity for students to pursue individual projects is a key part of teaching at UCPH and this will allow students, who are particularly motivated, to follow up specific Geodesign themes outside the course regime. This ad hoc activity is often a precursor to master's thesis work and the active promotion of such endeavour is important.

Querry and Fisher, at the conference, gave examples of the nomadic classroom. Both explained teaching situations 'in the field', where online working and portable devices made this possible. The potential for this will be important in varying teaching styles and tailoring teaching to specific situations. Another development that is going on at UCPH, is the improvements to model-making facilities and interfaces with digital working. In 2015, vertical data projectors will be installed in the studios at UCPH as an aid to design processes.

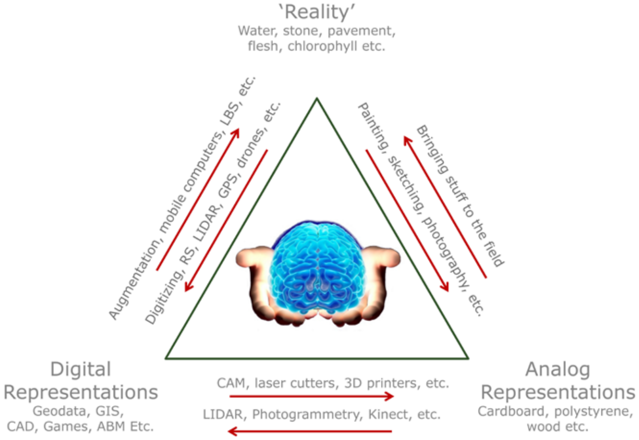

Figure 2. Representations and the real World.

Other opportunities exist to involve the departments' model lab. Here there are many possibilities to merge or entangle studio and digital model representations in teaching and research. At the same time the ability to bring digital model representation to the field is currently rather limited. Accordingly bridging the real world, and representations through studio models and digital models will be a core of future development of Geodesign at the department (Figure 2).

In terms of software and interfaces, improved understanding of programming and gaming, students arrive with will be harnessed. This will become increasingly relevant as game engines further outstrip GIS and CAD systems, particularly in terms of visualization. This is the case for static images, viewpoint movement, and moving objects (humans, wind turbines, cars etc.), and environments with shadows, clouds and water bodies. For students increasingly used to computer gaming, a game-like approach to design process would seem an obvious area for pedagogical investigation. As suggested by Elliot Hartley during the conference, the linkage of City Engine and Lumen-RT (2014) appears to be promising. Along the same lines, the use of games and apps will also be a continuing focus. Minecraft version of the Danish land use and terrain model is available (Danish Geodata Agency, 2014b; Minecraft 2014) and the use of Minecraft in early design training and as a platform for geospatial reasoning and learning should be considered.

In the future, interfaces between digital and physical 3D will be further explored. Areas of interest include technologies that can scan studio models and create geo-rectified representation that can be imported into CAD/GIS. These for instance can be indoor LIDAR, static photogrammetry, and Kinect sensors. Moreover, technologies will enable students and researchers to bring digital representations (geodata, 3D models etc.) to the field. These technologies include augmentation (2D/3D), location base services, online/on-site GIS etc. This investment is a combination of analogue, hardware and software, and will be matched by continued investment in staffing and staff development.

As Geodesign takes root and understanding of the potentials grows, it is expected that a key aspect of the work of research, and teaching, will be exploring the potentials of technology. Being asked new, and sometimes unanswerable, questions will be an important part of this development, and Geodesign as a framing concept of teaching and research, will challenge GIS as a data model, as analytical tool, as well as a science by itself. Research questions raised by these developments at UCPH will include issues of data quality, human movement patterns analysis and prediction, sociological data, ecosystem services and sustainable urban drainage and storm water management.

In addition to the current bachelor level course the aim is to develop courses at master level. Such courses can be extended along the lines drafted above – both in terms of design/technology involvement and the integration of digital/studio representation and the real world.

Through teaching and research that builds on the strengths of the Landscape Architecture programs at UCPH, and increasingly involving colleagues from across the five sections of IGN, it is hoped that a distinctive strand of Geodesign will begin to develop. At this initial stage, the focus is, perhaps appropriately, on harnessing Geodesign as a means of facilitating improved teaching and cooperation internally at the department. This initial impetus is strong, and future stages of the development of Geodesign will be discussed and debated vigorously in the coming years. As students and teachers/researchers are picking up digital work methods as a natural part of design processes, it can be expected that such techniques will be absorbed in topics and processes taught throughout design courses of the education.

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Geo-design: Advances in bridging geo-information technology, urban planning and landscape architecture

Geodesign is a GIS-based planning and design method, which tightly couples the creation of design proposals with impact simulations informed by geographic contexts. Geodesign as such comprises a set of geo-information technology driven methods and techniques for planning built and natural environments in an integrated process. It includes project conceptualization, analysis, design specification, stakeholder participation and collaboration.

This academic publication brings together a wide variety of contributions from authors with backgrounds in urban planning, landscape architecture, education and geo-information technology presenting the latest insights and applications of geodesign. Through focusing on interdisciplinary design-related concepts and applications of GIS international experts share their recent findings and provide clues for the further development of geodesign.

The book originated at the Geodesign Summit Europe (2014) held at TU Delft’s Faculty of Architecture and the Built Environment preparing grounds for in depth discussions and future collaborations. This is important since there is still much work to do. Not only in the development of geo-information technology, but especially in bridging the gap with the design-disciplines.