The Rise of the Smart Circular City
Intelligent Modelling of Cities for Improved Waste Reuse and Environmental Effects

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Chapter 129
The Rise of the Smart Circular City: Intelligent Modelling of Cities for Improved Waste Reuse and Environmental Effects

R. Vrijhoef

129.1 Introduction

In the Netherlands alone the potential of the circular economy for the economy is estimated at an annual cost saving effect of 7.3 billion Euros and job creation of 54,000 jobs (Bastein et al. 2013). However this potential needs to be used in applied solutions in often local settings such as cities. Cities are reliant on local development for their employment, business activity, and reduction of energy consumption, waste and air pollution in the city. In these areas cities feel more and more pressure and they set high ambitions.

Last few years particularly cities have restrained the entering of polluting vehicles and improving the inner-city climate and air quality in general. Particularly construction transport is relevant to this aim while typically 30–40% of all transport is related to construction traditionally. This represents some 40% of vehicle emissions and road congestions. Governments and road users are keen to reduce this. While load factors of construction transport tend to remain structurally under 50%, in few cases down to 15% of their loading capacity a need to act is felt urgently (Vrijhoef 2015).

Another aim of the circular economy city is that waste is re-used from demolished buildings into new design solutions for the built environment. To establish this circular city, there is a need of information on various levels in an open source structure. Examples of such data need can be, where and when is what kind of building material needed, and where can building materials be gained by demolishing buildings? For these kinds of questions, a smart 3D city model is proposed.

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This model should contain various types of intelligences, like GIS-BIM integration and real time and modelled environmental data. The combination of data creates new, innovative possibilities for the built environment (Heere et al. 2016).

129.2 The Idea and the Potential of the Smart Circular City

In this paper we conceptualise the smart circular city by a 3D city model aimed at improved reuse of construction and demolition waste (CDW) and reduced impact on the environment. The Ellen MacArthur Foundation, a "global thought leader" in the field of circular economy, defines the circular economy on their website (www.ellenmacarthurfoundation.org) as follows: "A circular economy is one that is restorative and regenerative by design, and which aims to keep products, components and materials at their highest utility and value at all times, distinguishing between technical and biological cycles" (Ellen MacArthur Foundation 2012).

For the built environment, focus is on eliminating waste through re-use of materials and re-designing building components, systems and logistics. Most materials in the construction industry are part of the technical cycle as defined by the Ellen MacArthur Foundation (2012). This means we should design for remanufacturing and refurbishing to keep components and materials circulating in, and contributing to the economy. Circular systems use tighter, inner loops (e.g. maintenance, rather than recycling) whenever possible, thereby preserving more embedded energy and value. The technical cycle involves the management of stocks of finite materials. Use replaces consumption.

In general 40% of all raw material flows are related to building and construction. Reusing CDW is no new phenomenon in the construction industry. Already some three decades ago the urgency for reuse increased by the great demands for building materials. However compared to that time, currently technical possibilities to separate and reprocess CDW to be reused in new projects have increased dramatically. The demolishment in itself will cost extra labour (estimated 10%) and costs for control and compliance, but this is compensated by higher revenues of raw materials and preventing dumping costs. Preferably supply and demand would meet 'just in time' (Cramer 2015). However in practice, it is to be expected that meeting supply and demand will need digital support such as smart city data models.

129.3 Modelling the Smart 3D City by Integrating BIM and GIS

In the context of this paper and the digital 3D city model, a circular city could be described as an industrial and economic system where re-use of products and materials add value to every link in the system. By linking the information a tool can predict which route and which traffic system is the best to transport materials in the city (Vrijhoef et al. 2016).

For a circular city is important to know how much materials and resources you have available within the boundaries of a city, or, as Zhu states, "(…) location-based information or location intelligence about waste and recyclables and their potential stocks and values can help identify actions to build capacity, ensure an appropriate suite of services is available to communities and assist in site selection of waste collection facilities and the recycling industry in order to maximise economic benefits and minimise environmental impacts" (Zhu 2014). The city can turn into an urban mine, where resources can have a new meaning within the city.

Within the city there are various data resources that can help us to make the city more sustainable. Resources such as cycloramas (very detailed 3D panoramic photo imaging), point clouds, City Engine, traffic information, etcetera can provide us with very detailed and real time data. All these different types of intelligence can be combined into the 3D spatial city model, hereby we have the ability to show real time traffic information and real time and modelled environmental data. This combination of data establishes valuable information for the built environment (Heere et al. 2016).

The visualization of the urban mine makes it very easy to use materials from within the city. Most of these materials have been used in other buildings, infrastructure, industries or products and can be re-used (Cossu and Williams 2015). Within our research group an investigation has been done to develop a renovation with used materials from another building (in this case from the same owner). This investigation has been done to find out which information needs to be known about a resource and to see if this can be done by comparing different (BIM)models. This comparison can be done using a Building Information Model (BIM), but it can be more valuable if we integrate different types of information such as BIM and GIS and distribute this information (Heere et al. 2016; Fig. 129.1).

To make the developments and processes described above efficient, good data management is important. There is a need of data about the buildings, which are to be built or demolished and the surroundings of these buildings, including the infrastructure. A 3D city model is an effective way to manage these data. These models can handle an increasing number of tasks concerning environmental issues, like noise mapping, training simulators, disaster management, architecture, and city planning (Stadler and Kolbe 2007).

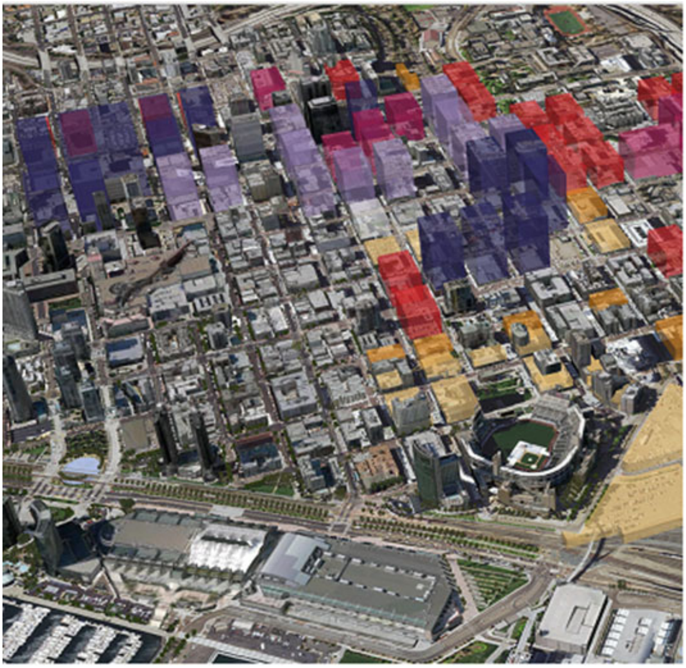

Fig. 129.1 Visualisation of integrated information from BIM and GIS. *Source* https://blogs.esri.com/esri/arcgis/files/2016/04/BIM-GeoDesign.png

129.4 Examples of Cities and Applications of 3D City Models

In various cities 3D city models have been developed (Fig. 129.2). In London thematic information has been displayed on a 3D city model and tools for city planning have been added (Source: http://www.geoinformatics.com/cybercity-3d-creates-3d-interactive-maps-to-help-cities-visualise-their-future. Seen: December 2015). The Planning Support System (PSS) for the City of London contains a 3D city model, data and the calculation rules, necessary for thematic analysis. In Berlin an open 3D city model has been developed that can be used by inhabitants and firms in the city (Source: http://www.3dcontentlogistics.com/en/solutions/demos/berlin-3d-city-model-smartmap-web/, seen December 2015). Shanghai applies a virtual reality theatre for city planners, architects, city officials and inhabitants and firms to collaborate. In Rotterdam and other Dutch cities digital city models have been developed e.g. to check building activities to building regulations (Stadler and Kolbe 2007).

Various types of analyses have recently been developed in 3D modelling such as establishing optimal solar panel orientation on roofs (Fig. 129.3).

Fig. 129.2 Examples of 3D city models of London, Berlin, Shanghai and Rotterdam (clockwise from upper left corner)

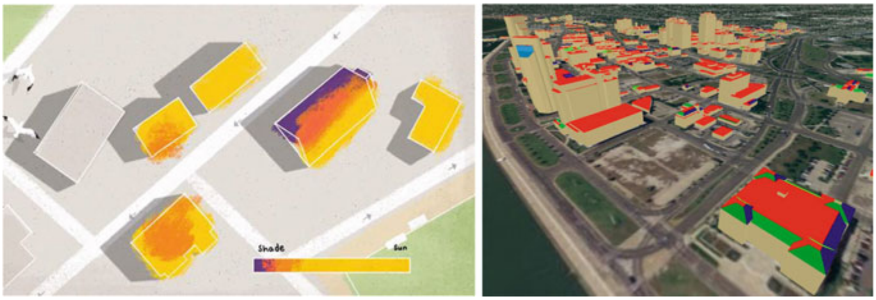

Fig. 129.3 Roof orientation analyses in 3D for optimised installation of solar panels

129.5 Case Study of a City Area in the City of Utrecht, Netherlands

The ongoing research this paper is based on originates from the idea to develop an integrated and open 3D data modelling platform for cities and city areas to do multi-thematic analyses for various aims such urban mining for increased reuse of construction and demolition waste and increase the insight in environmental impact.

In this case we looked into the area of the City of Utrecht called 'Werkspoorkwartier'.

A literature study has been conducted to find similar studies that have also done research on this topic. The conclusions en findings of a number of these studies were used in the rest of this study. A theoretical study has also been performed in which all of the key concepts and techniques that are involved when making 3D city models are explained. To determine the functions and purposes of a 3D city model, interviews were held with stakeholders like the city of Utrecht.

129.5.1 3D Smart Modelling of a City Area Based of Existing Data

Most data sources needed had appeared to deliver free and open data, making them very suitable to serve as a base for the rest of the 3D city model. Apart from these two data sources, there are many other data sources in the Netherlands which are available as open data. Many of the data sources which have been examined are not yet suitable for 3D, or are not free of charge.

To investigate what the possibilities were related to sharing the 3D city models, previously used software was looked at. Since all of the used software is made by Esri, it soon became clear that ArcGIS Online at the moment is the most suitable platform to easily and quickly develop open 3D city models. Adding rules to existing and readily available data appeared to be another suitable technique to develop smart and open 3D models, i.e. useful for multiple analytical purposes (Heere et al. 2016; Fig. 129.4).

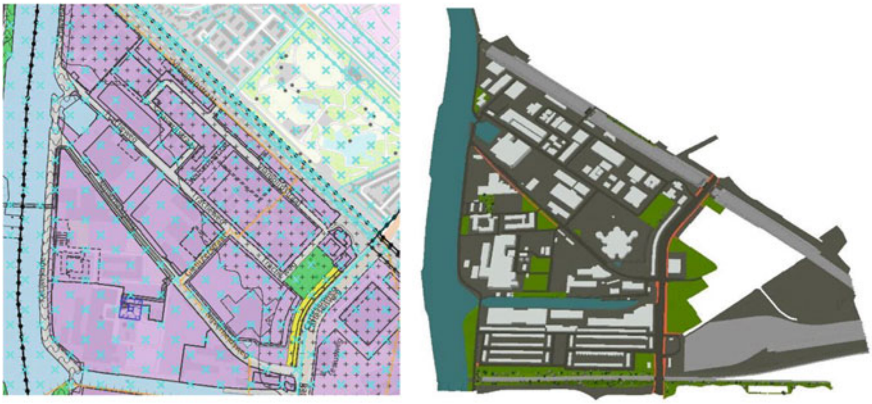

Fig. 129.4 Abstracting available maps and adding data rules to existing data and maps to develop a 3D city model

129.5.2 Applying the 3D Model for Improved CDW Reuse

In the time of the 3D model development in the City of Utrecht the business case was studied for reuse of construction and demolition waste (CDW). For ten housing projects with a prospected number of around 10,000 houses to be built in Utrecht the potential demand for CDW and interests of stakeholders were analysed.

Particular interest was for buildings about the same age and their possibility to use large quantities of the same raw materials from the demand and supply side. To determine which raw materials, materials and products are of interest, information and data from various sources have been collected, added to calculations models and studied, including governmental databases freely available and historic building and project data. Further analyses showed potential materials transfers from buildings being (partly) demolished (so called 'donor buildings') to buildings that would need materials to be built or renovated (so called 'receptor buildings') (Fig. 129.5).

129.5.3 Applying the 3D Model for Noise and Emission Analysis

The second application of the model was adding environmental data to the model. More specifically this included available traffic data from local traffic control and registration services and databases, and data of noise and greenhouse gas production by types of traffic passing. Noise models and emission calculations applied by governments and specialists concluded on 3D noise and emission profiles of infrastructure and their impact on buildings around (Fig. 129.6).

Fig. 129.5 Collecting and comparing data of buildings being (partly) demolished thus supplying materials ('donor buildings') and buildings in need for materials ('receptor buildings') (Jochemsen 2016)

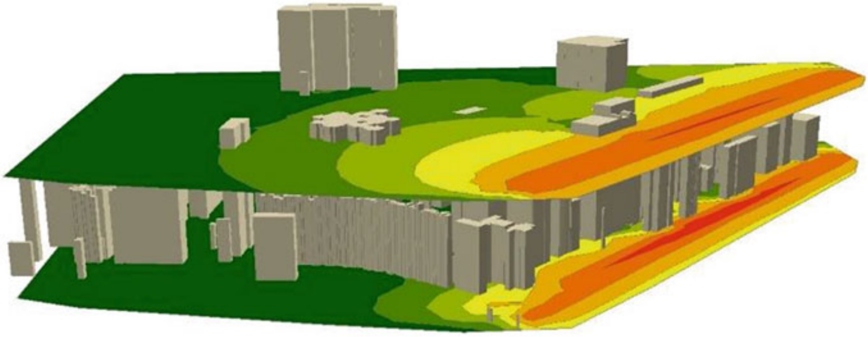

Fig. 129.6 Noise profiles visualised in the 3D city model of Werkspoorkwartier on 3 and 15 m height (Jochemsen 2016)

129.6 Conclusion

In this paper we explored the concept of the smart circular city and particularly the intelligent modelling of cities in order to do thematic analyses and gain insights to improve the circular aspects of cities such urban mining for increased reuse of construction and demolition waste. The applications of smart 3D city models would be capable of facilitating improved urban distribution and traffic control too and thus the decrease of greenhouse gas emissions.

Notwithstanding the potential benefits and applicability of 3D city modelling for circular and environmental aims in this seminal paper, further research needs to be done in these directions. Particularly this applies to the further development of the 3D city model as an open and multi-thematic platform for various calculations and analyses

More specifically the proposed smart 3D city model distinguishes itself from traditional models by adding open data and analytical functions to the model, like environmental data and tools, so that the model is used for communication, analysis and decision making purposes.

The potentials advantages of such a smart and open 3D city model in urban planning are various. It could include multiple views on data analyses with higher and lower abstraction levels, and therefore useful for anyone. It can contain or be connected a lot of data and databases, which improves the quality of the analyses done through the model. The calculation modules linked to the model could be available to anyone involved with urban planning, not only professionals but also inhabitants of the city.

This would make the smart ad open 3D city model a very powerful tool. None of the 3D city models currently available do this, and none of them contain so much data and functions so to be useful to professionals as to the wider public. This will need further research with potential partners including local government, firms and universities. This paper is aimed to be another step in that process achieving the smart circular city.

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