URBAN DESIGN STRATEGIES FOR THE UPCYCLING OF URBAN INFRASTRUCTURE RESIDUAL POCKETS: 3D CITY MODELLING FROM OPEN DATA AND LOW-COST RAPID MAPPING TOOLS

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ABSTRACT:

This paper deals with the 3D City Modelling specific procedure developed as a tool to support strategies for urban regeneration, within the framework of the B-ROAD research project.
The B-ROAD research project, whose acronym stands for Below the Road, is developing urban design strategies for upcycling urban infrastructure residual pockets.
The B-ROAD's methodology is conceived as research by design as it is carried out by creating pilot scenarios, disclosing the latent and still unexpressed potential of these wasted areas and displaying their potential transformations, to turn them into precious resources for the contemporary city.
The 3D City Modelling of the study area has proved to be essential and strategic yet often complex and critical as most of the spatial and architectural features of B-ROAD spaces, as well as their potential, cannot be detected nor represented through the traditional means of representation of urbanised land, as aerial survey-based representations, or GIS. Likewise, traditional, or even cutting-edge, survey techniques that can be used to acquire missing data are often costly and time-consuming, thus making it hardly impossible to achieve the purpose of extensive and deep knowledge of such a vast area. Thus, 3D City Modelling aimed at examining spaces and providing a final representation of pilot scenarios has been a crucial stage requiring a specific in-depth study.

1. INTRODUCTION

According to the United Nations projections, by 2050, the world population will continue growing (United Nations, 2022); meanwhile, the annual percentage of people residing in urban areas will increase from 57.0% (2022) to 68.4% (United Nations, 2018). The mentioned data would imply a proportioned growth of urban areas; nevertheless, such an extension of built land appears incompatible with the pressing and current topic of environmental sustainability. Stemming soil sealing is a priority; however, urban growth frequently conflicts with safeguarding rural and unbuilt areas. As many European Union reports have emphasised, the preservation of rural land has a positive global impact on the economy, food safety, biodiversity, and land safety, as well as mitigating the effects of climate change (European Commission, 2020). Furthermore, numerous studies concerning the matter - upon which land preservation strategies are founded - have successfully shown that inaction can be considerably more expensive for our communities than any action for land preservation (Nkonya et al., 2016). For instance, in Europe, the costs of inaction are estimated to be six times higher than those needed for the preservation and/or rehabilitation of jeopardised soil (Nkonya et al., 2016, p. 156).
Moving forward, containing land consumption has proven to be essential for the future development of cities, thus imposing a halt to urban expansion. Accordingly, assessing the data on population growth and urban population increase in a global scenario aimed at applying environmental sustainability strategies, it can be speculated that future scenarios will see an increase in the population density of cities.
In order to mitigate this density, further urban soil should be found inside, rather than outside, already urbanised land, meaning optimising land use by exploiting decommissioned, underused, and wasted areas within the urban perimeter. Several standard cases of urban wasted areas, which have been extensively studied so far, can be found in decommissioned industrial, military, and infrastructural districts, while some other strategies for optimisation focus on well-established and/or historical urban fabric. Nevertheless, additional and often underestimated reserves of urban space still exist, whose study can represent an innovative field of research for the upcycling of urban spaces. Namely, scraps of urban space which are not conventionally acknowledged as architecture, part of the city or landscape and are situated below, besides, in the vicinity or next to pieces of infrastructure such as viaducts, bridges, road junctions, and roundabouts. These places constitute an outstanding reserve of unused space that could contribute to sustaining the rise of population density in our cities. On this basis, the B-ROAD research project (1), whose acronym stands for Below the Road, is developing urban design strategies for upcycling urban infrastructure residual pockets, converting them from waste to resource. The B-ROAD project focuses on the interactions between architectural, urban, and landscape design and infrastructure for people and goods mobility aiming to contribute to optimising the use of urban areas and creating new liveable and desirable spaces for people. (LS, RS, MC, VC, AdL)

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(1) *B-ROAD_Below the Road. Pilot scenarios for the upcycling of urban infrastructure residual space*, two-year research project selected and funded in the framework of the call Finanziamento della Ricerca di Ateneo, FRA 2020, University of Naples Federico II. Research Team: Luigi Stendardo_Architectural and Urban Design (Principal Investigator), Vittorio Marzano_Transportation Engineering, Valeria Cera_Representation of Architecture, Raffaele Spera_Research Fellow.

2. B-ROAD'S PURPOSES

The B-ROAD research project aims to achieve two main purposes. Firstly, it deals with producing knowledge about B-ROAD urban areas through collecting data and describing their potential architectural features, given that they have never been regarded as urban spaces thus far. B-ROAD spaces (Figure 1) are often perceived as hostile, unclean, and treacherous places. This common belief, though often justifiable, is, in fact, the effect of a misunderstanding, namely an ambiguity between ethics and aesthetics. What is perceived as immoral, illegal, or socially dangerous is considered unappealing, despicable, undesirable or unworthy as architecture or public space (Stendardo, 2016).

Figure 1. B-ROAD spaces in the East Side of Naples.

Additionally, the project deals with developing pilot scenarios, disclosing the latent and still unexpressed potential of B-ROAD spaces to turn wasted areas into precious resources for the contemporary city.

Both purposes mentioned above are achievable through the two following fundamental stages:

- establishing the difference between ethical and aesthetical issues;
- acknowledging B-ROAD spaces as formally worthy materials for architecture, urban space, and landscape.

Whereas the former stage might be accomplished through dialectical steps, the latter would need a longer analogic discourse, mainly constructed through images featuring the potential architectural attributes of B-ROAD formal elements. In this perspective, a road, or more specifically a flyover, should not be regarded as a mere utilitarian link between two points but as an element capable of generating liveable spaces for the community. As a result of this premise, the need to acquire physical, geometrical, and dimensional data about roads arises, as well as the demand to define the architectural features of the spaces generated by flyovers, i.e. the ratio between their height overground and their width, the distance between the lower surface of the viaduct and the roofs of the buildings below, the texture and the finish of materials, the way sunlight drifts through overpassing infrastructural lines and hits the ground, the way building elements such as pillars and beams frame the landscape. All these spatial features concerning the space's quality belong to the architectural design scope. Assumed these elements are properly measured, described, and managed (i.e., they are an object of knowledge) as well as efficiently illustrated to a wider audience of common people, professionals, administrators, citizens, and stakeholders (i.e., they are an object of dissemination), these formal statements can effectively support the reasoning towards an unambiguous distinction between ethical and aesthetical issues concerning B-ROAD spaces. Above all, this would contribute to shifting the prejudice concerning the supposed "ugliness" of B-ROAD spaces, which is the first step to acknowledging them as worthy and suitable for architecture, urban space, and landscape. (LS)

3. B-ROAD'S METHODOLOGICAL APPROACH

Besides the well-established research activities concerning literature survey, data collection and management, and the processing and implementation of models, the B-ROAD's methodology is conceived as research by design as it is carried out by creating pilot scenarios, displaying the potential transformations of B-ROAD spaces. These pilot scenarios are intended as open-source outputs that can serve as a basis for future further processing and development projects and can be used by other research teams, professionals, administrators, and stakeholders to prefigure future scenarios and support decision-making processes. Thus, B-ROAD's scenarios must undergo several reviews concerning their feasibility in terms of technical, economic, social, and environmental sustainability.

Research by design organically implies the choice of some significant case studies to develop pilot scenarios; to this end, B-ROAD has focused on the East Side of the city of Naples (Figure 2). This urban district has proven to be a key field of inquiry for the B-ROAD project because of two main features. The former stands on its manifold orography, rich with heights, slopes, and drops, constituting an extraordinary urban landscape. The latter is the existence of a complex, widespread, and dense infrastructural network that overruns this district. The interaction between the geographical and the infrastructural systems has generated a various and wide set of in-between spaces, which present different forms, positions, extensions, and mutual relationships. Moreover, the variety of infrastructural networks across the East Side of Naples, featuring railways, motorways, and oil pipelines, is associated with the existence of several relevant logistics hubs, such as the harbour, the main railway station, the airport, many container yards as well as to a wide industrial district rich with oil and petrol tanks that are gradually being decommissioned. As a result, the district is expected to undergo radical urban regeneration, including a large urban park, buildings for retail and business, housing, and several facilities.

Figure 2. The East Side of Naples. The main infrastructural lines are highlighted

In order to achieve a high level of knowledge of B-ROAD spaces within the East Side district, to support the creation of pilot scenarios as described above, the 3D city modelling of the whole area proves to be essential and strategic yet often complex and critical as most of the spatial and architectural features of B-ROAD spaces, as well as their potential, cannot be detected nor represented through the traditional means of representation of urbanised land, as aerial survey-based representations or GIS. Likewise, traditional, or even cutting-edge, survey techniques that can be used to acquire missing data are often costly and time-consuming, thus making it hardly impossible to achieve the purpose of extensive and deep knowledge of such a vast area. Moreover, as a further obstacle, B-ROAD spaces, which are situated in the in-between interludes of infrastructure, are often physically inaccessible due to the extensive net of lanes and highways surrounding them and the troubled social environment that frequently afflicts them. Thus, in the framework of objectives and methodological strategies of the B-ROAD research project, 3D city modelling aimed at examining spaces and providing a final representation of pilot scenarios has been a crucial stage requiring a specific in-depth study. (RS)

4. 3D CITY MODELLING IN B-ROAD

4.1 Principles and issues

Historically, the preferred graphic form for analysing the complex phenomena characterising cities is the planimetric representation, presenting the relationships occurring in the territory through what could effectively be described as an anthropocentric key (Balestrieri, Cicalò, 2020). The Geographic Information System (GIS), the most established technology among urban planners and planners responsible for collecting, storing and analysing georeferenced spatial data (Goodchild, 2009), is deeply rooted in this projective system. Such spatial representations hold the undisputed advantage of enabling the processing of considerable amounts of data, which are undoubtedly significant for guiding planning actions. By organising georeferenced spatial data around attributes, GIS generates a database that provides essential support to queries and statistical analyses, which are key for spatial representation and analysis. Due to the relevance of this very attribute, GIS has become a broadly utilised tool throughout the previous decades, compared to other 2D applications that do not provide the same features, thus becoming the central instrument for cognitive action and analysis and, in more general terms, for the representation of the city in a digital environment, to the point that several applications have been developed employing 2D spatial data in a GIS environment to provide spatial analysis, statistics as well as simulations and forecasts (Lin, Chen, 2015).
However, 2D GIS does have an important limitation which lies in considering mainly quantitative information, not allowing the quality of places to be captured where this is primarily contained in the third dimension of the spaces themselves, as traditional, two-dimensional systems of geographic information tend to flatten altimetric variations, reducing the representation of the city and the environment to the horizontal plane, making it extremely difficult to understand the complexity of the spaces depicted. Orographic variations, suspended urban infrastructures, and large upwards-projected buildings are all elements that contribute to the unique picture of an urban section, connoting its aesthetics and orienting its perception. For this reason, over time, people have resorted to representation systems that, varying from historical views to Patrick Geddes's sections (Geddes, 1915) up to 3D City Modelling and 3D-GIS, attempt, each to its own degree, to restore and convey the spatial articulation of the territory.
Engineers and town planners have been continuously searching for the best way to plan and organise cities, managing the complexity of urbanisation, starting from representations and visualisations that are effective and performant (Uddin et al., 2021). In this sense, three-dimensional modelling has played a central role due to its ability to visualise and simulate real cities and show possible future scenarios. The first 3D city models date back to the end of the XX century when their primary use was the mere graphic representation and visualisation of urban areas. Currently, however, their application is increasingly expansive and extensive due to their ability to provide important information for the city's different stages of design, construction, use and management and its characteristic elements, including urban infrastructure (Borisov et al., 2022). Undoubtedly, the advent of the digital era has provided a significant stimulus, as new systems for visualising and managing geographical data within web platforms and/or specific applications such as Google Earth and Google Street View have impacted the approach to urban knowledge and experimentation (Li, Ratti, 2019).
Operationally, the migration towards 3D space, i.e., 3D City Modelling, has taken the form – as mentioned – of different software and tools.
Firstly, GIS has progressively evolved into 3D-GIS, in which two-dimensional geographical data are modelled in a three-dimensional environment using advanced computers that provide optimal visualisation with minimal effort (Elwannas, 2011). Undoubtedly, the spread and progress in the use of three-dimensional GIS systems are also linked to the development of CityEngine: a stand-alone desktop application that uses the CGA Computer Generated Architectures integrated programming language for the design, planning and modelling of 3D urban scenarios utilising mathematical rules and algorithms (Xia, Qing, 2004). Similarly, several software packages, such as ESRI ArGis3D and Autodesk Infraworks, have been implemented, featuring rather close affinities with GIS. At the same time, there is no lack of 3D City Modelling approaches conducted in different modelling environments, e.g.,

based on the combined use of Rhinoceros and Grasshopper (Costantino et al., 2022).

Regardless of the operational solutions adopted, the 3D representation of the city allows urban planners to make qualitative and perceptual evaluations based on the analysis of the visual impact of squares and streets at a macro level, as well as to control the shape, height and colour of buildings, and thus the architectural quality of an urban area, at a micro level (Badwi et al., 2022).

However, as one can easily imagine, modelling built urban tissue requires massive data collection as well as reliable and accurate information for visualising the state of the site (Campi et al., 2022). Besides this, data collection has been urgently demanded to meet the requirements of timeliness and speed in processing information to allow for analysis and formulation of possible design scenarios that follow the frenetic dynamism of the creative process.

Due to this, in B-ROAD, priority was given to the adoption – and subsequent implementation – of three-dimensional representation tools to allow a dynamic and qualitative exploration of space, in line with the general objectives of the project, thus not limited to a mere measurement of quantitative data.

Furthermore, the 3D City Modelling approach adopted uses 3D modelling software on a GIS system in which the input data are open source to reduce the initial information collection time. At the same time, as explained in the following section, having to meet the demands of reliability and veracity, the source data information was refined through a punctual digital survey campaign that employs capture tools for prompt and cost-effective mapping (Figure 3). (VC)

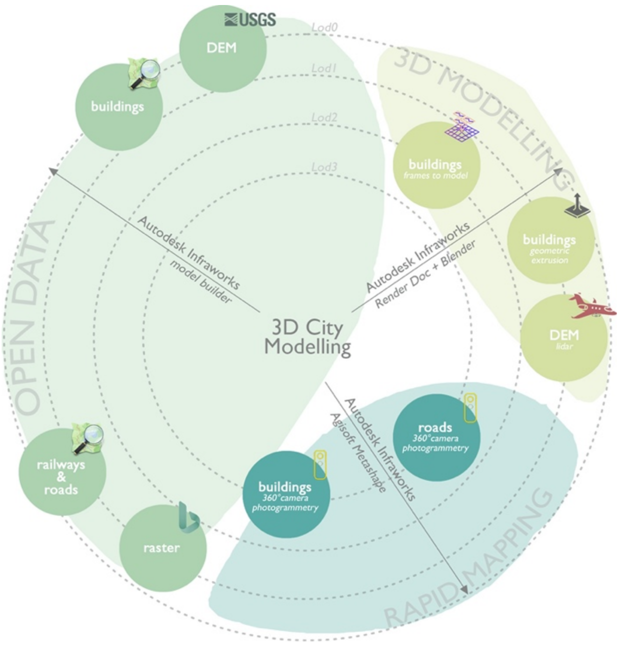

Figure 3. B-ROAD’s 3D city modelling methodology.

4.2 Methodological approach and first data process

The methodology developed in the B-ROAD project for urban modelling is strongly centred on the concept of the Smart City, conceived as a city in which the issue of Smart refers as much to the inclusion and participation in the planning of project actions as to the adoption of ICT solutions and KET'S integrated technologies (Balzani et al., 2020).

In this sense, the codified approach aims at utilising digitisation processes technologies that are optimised as well as expeditious in the data acquisition phase; at the same time, it pursues well-defined levels of accuracy and detail of the modelled elements per the objectives set by the project and, therefore, the end users. Furthermore, it resorts to low-cost technological solutions that allow the entire procedure to be replicable in contexts that appear similar due to conditions of physical accessibility and the difficulties of the socio-cultural environment.

Undoubtedly, the uniqueness and variety of the urban tissue can make defining a distinct method for understanding and representing the built environment rather complex, especially when working in extremely historicised and stratified contexts such as the city of Naples. However, finding an information system that can overcome the specificities of individual contexts is becoming increasingly urgent, allowing sharing of knowledge and managing the built environment. The B-ROAD approach is oriented in this direction to codify a shareable and replicable knowledge protocol. Through the specific operational phases of 3D modelling, B-ROAD aims to define a knowledge construction process that makes the complexity of information progressively comprehensible to the variety of audiences it addresses. This way, the community can be involved in decision-making by providing clear, accurate, realistic visual models and figures.

Bearing this in mind, the modelling of the project study areas was prompted by exploiting some open data as starting information to reduce the time for the initial collection of massive amounts of starting data - as mentioned - and to set up a replicable workflow.

In particular, (i) the orography of the terrain was assumed in the first instance as a DEM from SRTMGL1, NASA's Shuttle Radar Topography Mission, with a 30-metre pitch for the project latitudes; (ii) the buildings, highways and railways were derived from the OpenStreetMap database; (iii) the raster images applied to the DEM were processed from Microsoft Bing Maps satellite images (Figure 4).

This body of information was downloaded directly and processed in the Autodesk Infraworks software, one of the diverse solutions available today for 3D City Modelling.

The choice of Infraworks as a platform responds to the satisfaction it guarantees in terms of interoperability with other urban analysis and planning tools, as it supports the exchange of data between the Autodesk suite - widely used by design professionals -; it allows direct input and output integration with GIS systems such as ArcGIS - a preferred tool of urban planners -; finally, it allows to import into the 3D model and work with large sets of data generated from three-dimensional surveys in the form of point clouds (LIDAR, laser scanners, photogrammetry) and/or derived polygonal models.

Besides this, the software allows an adequate degree of detail and control in the modelling of the different components of the urban environment, which is considered suitable in terms of attributes and working time for the purpose of the research.

Starting, therefore, from the importation and initial processing of the open data through the Infraworks Model Builder, a basic representation of the area of interest was defined, on which progressively detailed modelling operations were carried out. For this action, reference was made to the City Geography Markup Language, which defined how to describe most of the features and 3D objects most commonly found in city contexts (such as buildings, roads, bridges, vegetation and street furniture). Therefore, in line with the industry standard, the 5 Levels of Details of the CityGML Open Geospatial Consortium (Biljecki et al., 2016) were taken as the reference for structuring the geometric and semantic characteristics of 3D data.

In particular, for the purposes of the research, four consecutive well-defined LODs were considered: the LOD0 defined as a highly generalised model; the LOD1, i.e., a model obtained as an extrusion of basic elementary geometries; the LOD2, i.e. a model that is realistic in form and visual appearance, yet still generalised; and finally the LOD3 which features a more detailed model in terms of information attributes (Kutzner et al., 2020).

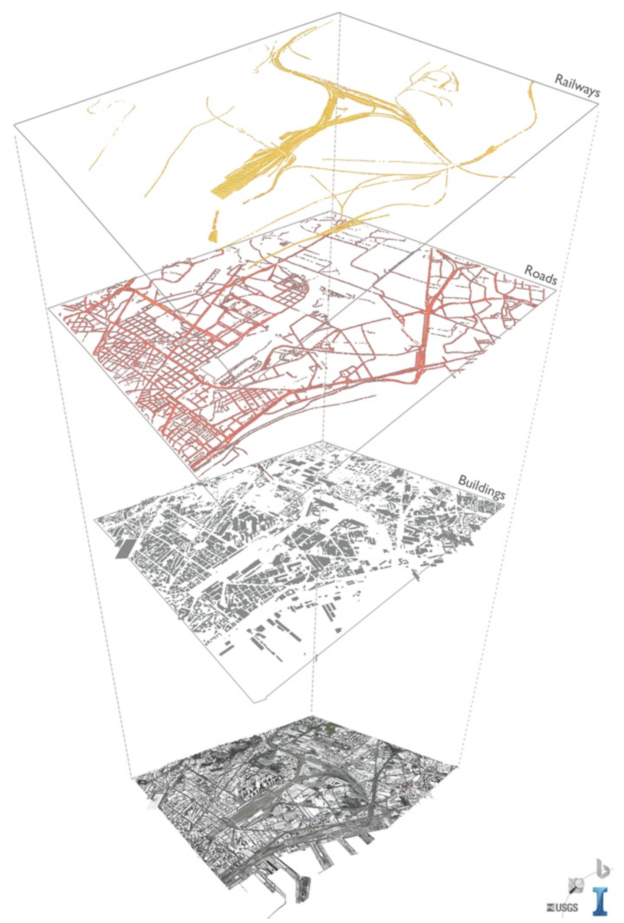

Figure 4. Preliminary model obtained from the open data as LOD0.

Accordingly, considering the model obtained from the open data as LOD0, the methodological modelling process was articulated in three further stages, some specifically aimed at correcting the starting data, others to enhance the information: (i) correction of the DEM in significant specific areas starting from LIDAR data with a 5-metre definition step; (ii) detailed LOD1/LOD2 modelling of the built tissue to restore the urban and architectural quality of the places; (iii) detailed LOD3 modelling for the infrastructural elements – the roads – characteristic of B-ROAD.
A simple comparison between the model derived from the open data and a view from Google Earth of the same study area can exhibit that the currently available open-source data do not align with the real state of the places. The inconsistency affects parts of the terrain elevation model as well as the built elements (buildings that do exist in reality but are not present in the database or buildings that, according to the open-source data, appear to have shapes or heights that differ from reality). Therefore, as the first action of 3D remodelling, the initial DEM was corrected in some specific and significant areas, e.g. the Centro Direzionale area of Naples, as the elevation information proved to be clearly inaccurate. In order to do this, a new DEM was generated from more precise LIDAR information with a step between contour lines of 5 metres. The new terrain model was thus set as a reference for the ground level of buildings and other built structures (bridges, railways, roads).
Similarly, some buildings were corrected with the intention of pursuing a LOD1 or LOD2 level modelling, depending on the building considered. When creating 3D city models, the LODs determine the technologies for data collection, impacting the level of detail of the information to be collected. The areas examined feature buildings of diverse types. For almost all of them, the level of detail achieved was type 1. Therefore, using the 'Buildings' category already present in the Infraworks database, 3D models were generated from plans with simple geometries extruded on the z-axis. Clearly, these are parametric models conceived as sets of individual basic elements, such as vertical walls, number of floors, and roof, which can be remodelled on the basis of specific parameters and attributes impacting their geometry and visual appearance. With regard to some particularly significant elements, the level of modelling detail was brought to LOD2, primarily with respect to complexity and thus to the specification of form and texture. This approach was applied specifically for buildings that characterise the spaces under investigation in terms of image, vision and perception of the surroundings yet are not the subject of intervention. An example of this is the Miralles-Tagliabue underground station in the square of Centro Direzionale or the Sant'Alphonso church near Via Argine: as far as these elements are concerned, implementing the modelling process from scratch to achieve the real geometry and surface texture was considered too time-consuming since they are context buildings anyway. Because of this, 3D models imported in .obj. format were used in Infraworks, acquired by directly exploiting the three-dimensional data integrated with Google Earth via a frame debugger such as MIT's RenderDoc (Figure 5). The collected information, reassembled in the Blender software through a special add-on, was then exported for integration in Infraworks as textured polygonal models inserted into the scene by exploiting the geographical coordinates also obtained from the Google database. This way, the methodology set up once again makes use of an expeditious data collection in which, nevertheless, the information content is better defined.

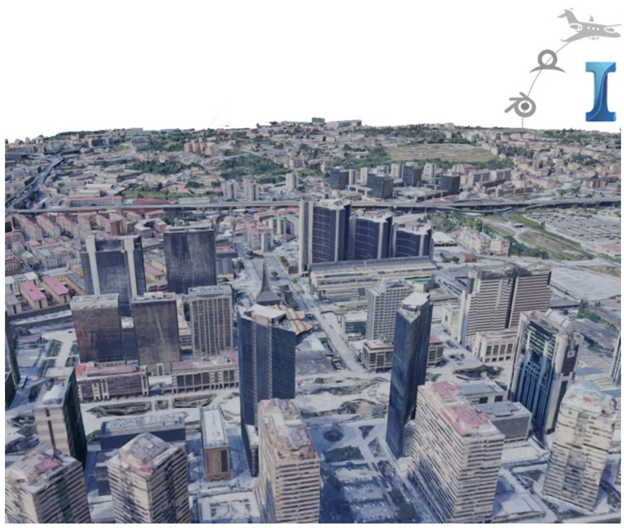

Figure 5. Model acquired via the frame debugger and Blender software.

Finally, for all those elements that are particularly relevant to B-ROAD, such as road junctions and the residual spaces that

characterise the urban infrastructures of bridges and viaducts in the examined area, the acquisition of data suitable for detailed modelling was oriented towards the application of rapid mapping and modelling tools and methods.
As these contexts, due to both their physical nature and the social environment that inhabits them, do not lend themselves to data collection operations for digitisation using sophisticated instrumentation, solutions were studied and applied to capture and process digital data quickly and inexpensively. Specifically, by exploiting Structure from Motion algorithms, various urban elements (such as viaduct pylons, elevated roads, etc.) were modelled from image-based point clouds, processed from spherical photographs acquired with a 360° terrestrial camera, the InstaOneX2. By installing the spherical camera on a special stand, photographs were taken with a distance between one station and the next of approximately 3 meters and a height above ground of approximately 1.80 meters. The acquired shots were then processed from image-based point clouds by means of the well-known SfM Agisoft Metashape app, which allows the direct processing of equirectangular images from which a point cloud is first reconstructed and then the textured polygonal model is triangulated with an algorithm derived from Delaunay (Figure 6). The latter was imported, in the .obj format, into Infraworks and used as the primary resource for modelling employing the Infraworks database's own element categories so as to obtain parametric objects with information attributes referring to geometry and visual appearance consistent with the LOD3 level. (VC)

Figure 6. Detail of the 3D model obtained with SFM algorithms applied to spherical images acquired by rapid mapping techniques (in red the acquisition points).

5. RESULTS

The procedure implemented for B-ROAD allows obtaining a 3D model of portions of the city that can, to all intents and purposes, be defined as multi-scalar: by moving from a general information base on a vast scale, the digital scene includes all the elements that characterise the city's dimension, presenting them with progressively greater levels of detail due to their specificity and importance in the general project of up-cycling the residual spaces. As highlighted in the previous paragraphs, the modelling approach was strongly focused on the use of open-source data and the definition of expeditious, inexpensive, yet accurate procedures for the collection and refinement of digital data. This is intended to respond, on the one hand, to the need to collect massive information in a short amount of time, and on the other hand, to the demand for data accuracy. If the first aim is achieved through the use of open databases and manipulation of the extracted resources, the second, represented by the use of 360° cameras, is seemingly the most critical one and is currently being further evaluated, though initial results are encouraged and support the validity of the approach. Acquiring some control points in the modelled area using spherical cameras, metric accuracy after bundle adjustment was evaluated. The RMSE values of the control points are 1.5 cm, 1.9 cm and 3.4 cm for the X, Y, and Z axes, respectively. Without prejudice to the need to extend the experimentation by varying the pace of acquisition and the method of capturing the data (e.g. by recording videos from which to extract frames instead of single photographic shots), these statistics show a degree of rather acceptable deviations from the objective of constructing a digital model capable of communicating the architectural qualities of a space, its aesthetics and the image that can be perceived of it.
3D city modelling, as conceived thus far, complies with two essential requirements of the research project as a whole. The former deals with presenting and enforcing B-ROAD spaces as elements which can be acknowledged as both worthy and capable of producing architecture. The latter concerns the presentation of pilot scenarios mainly addressed to academics, professionals, administrators, and stakeholders, though potentially useful to the general public, i.e. fostering a new perspective, imagination, expectations, and desires.
3D city modelling is suitable to visualise the architectural features of B-ROAD spaces displaying their progressive variations as the observer moves along the road, with respect to the changes in topography and urban fabric.
Furthermore, our 3D model supports the management of vast design areas, as long as they are defined as neighbourhoods (overlapping urban and mathematical meaning) originating from a significant infrastructural spot or hub. That is to say, extensions are not limited by any physical or administrative boundary but rather defined as scopes that can be stretched according to different influences and targets.
Since the different significant features within the neighbourhood do not play the same role and thus do not have the same relevance in each spot, the definition of the model must be differently adjusted throughout its full extension. This non-homogeneous level of definition determines a model where denser and less dense areas coexist. This last achievement has been made possible by the specific procedure implemented by the B-ROAD's 3D city modelling. (LS, RS, MC, VC, AdL)

6. FURTHER DEVELOPMENT

B-ROAD's 3D City Modelling process is bound to produce a variety of different outputs, such as scenarios, views, interactive maps collecting georeferenced data, and virtual and augmented reality to effectively present projects and support decision-making processes for academics, professionals, administrators, stakeholders, and citizens.
The pilot scenarios will be presented to different audiences using different ICTs to provide a significant impact both within the academic community and outside of it. (LS, RS, MC, VC, AdL)

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