AN INNOVATIONAL DIGITAL TOOL IN GIS PROCEDURE: MAPPING ADRIATIC COAST IN ABRUZZO REGION TO SUPPORT DESIGN OF SLOW MOBILITY ROUTES

A. Bianchi[1], D. D'Uva[1] *, A. Rolando[1]
[1] DAStU, Politecnico di Milano, 20133, Milan, Italy - (alessandro.bianchi, domenico.duva*, andrea.rolando)@polimi.it

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ABSTRACT:

The research work, object of this paper, is included in the "Fragile Territories" project of the Department of Architecture and Urban Studies of the Politecnico di Milano. It addresses the problem of mapping a territory, starting from the case studies of this issue in the contemporary scientific literature and trying to solve them by available raster/vector GIS database. The first innovation introduced with this research is the coding of an algorithm which takes as input the vectorized points from GIS and associates them with the heights transformed into z coordinates. The result is a three-dimensional grid of points. This grid is the basis for the creation of a single NURBS surface that will become the basis for the projection of all vector entities exported from the GIS into the modeler. In doing so, the result of the operation is a three-dimensional georeferenced NURBS model that contains all the vector entities in the territorial database.

1. RESEARCH FRAMEWORK AND CASE STUDY FEATURES

The research work, object of this paper, is included in the "Fragile Territories" project of the Department of Architecture and Urban Studies of the Politecnico di Milano. The aim of this research is to investigate innovative methodologies of representation that can support the design of improvements in the connections of a territory, overcoming the fragilities that prevent its organic development. The chosen case study is the *Costa dei Trabucchi*, in Abruzzo, Italy, a portion of territory that stretches along the Adriatic Sea for 45 kilometres and 10 kilometres inland. The central area of the Adriatic ridge is characterized by a particular territorial conformation in which the inhabited centres have been mainly developed in the immediate hinterland, leaving chaotically urbanized offshoots close to the coastline. Ortona and Vasto, too, the most populated urban aggregates of this stretch of coast are characterized by the same configuration, because the historic centers are higher than the sea level. The connection system of this territory is composed of the main networks running longitudinally along the coast, the A14 motorway, the railway and the S.S. 16. The transversal networks consist exclusively of roads connecting infrastructural nodes with population centres, which also lack railway stations for short distance connections. A paradigmatic case of this condition is Lanciano city center, which has both the railway station and a line that would connect it with the coast, but both are disused. On this territory there is a developing network based on soft mobility, created along the coast by the retreat of the pre-existing railway sediments, in progress at the date of this work, where solutions for slow, active and proximity tourism could contribute to encourage better uses of the territory and to improve its spatial quality. The first areas where this network is evolving are between Vasto San Salvo station in the south and Porto di Vasto station in the north. The second is located between the station of Fossacesia-Torino di Sangro in the south and Ortona in the north. The cycling areas are part of a longitudinal link project which may cross the entire study area, but at the paper drafting stage only a few stretches have been completed. Starting from this longitudinal network that is being defined, it is possible to think of extending the connections in a transversal direction, joining the hilly inhabited areas with an enhancement of the slow mobility system, based on the decommissioned railway network already present.

Figure 1. Case study area.

2. ISSUES

At the methodological level, a reference is the National Strategy for Internal Areas programme (SNAI) developed by the Agency for Territorial Cohesion, where the main peripheral and outermost areas are identified for each region. These fragile territories are far from the poles of attraction (large and medium-sized cities) and characterised by depopulation, demographic ageing and with a degree of accessibility issues to primary services (education and health) as well as poor infrastructure. The main target of the Strategy is the adaption of the quantity and quality of education, health and mobility services, and the promotion of development projects that enhance the natural and cultural heritage of these areas, reversing the trend of abandonment. SNAI is a partner of the DAStU Department of Excellence, which intends to promote research and educational activities related to the theme of Fragile Territories, in this case, starting from the Internal Areas (AI). The document consists of a list of areas classified by regions and differentiated between pilot areas (with processes already started) and SNAI candidates. The diversity of themes and stages of advancement of AI, makes it difficult and pretextual to try to group them into survey categories. For this reason, it was decided to provide the basic indications giving, through the reference to external links, the possibility of further investigations (1).

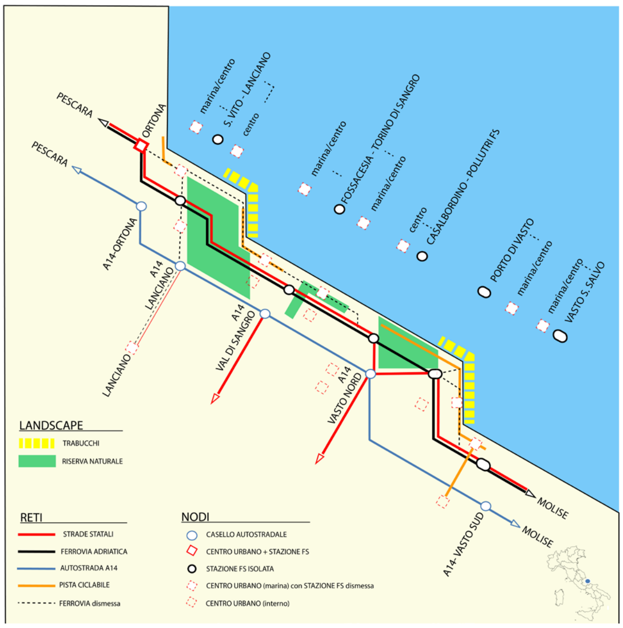

Figure 2. Connection network in its relation with urban areas.

In this area the main connections are located along the Adriatic ridge, leaving isolated the immediate hinterland where most of the population resides. This phenomenon creates fragility because the inhabitants of these territories have to travel along the secondary road network to move from the inhabited centers to the main nodes with private vehicles due to the inefficiency of public transport. On such a network seasonal flows are added that, in proportion to the summer tourist influx, undergo increases that create fragility in the transport system that cannot absorb the periodic increase in capacity, also because of the collective connections of little effectiveness and scope. To this end, an analysis of slow connections has been hypothesized both for coastal municipalities and for hilly municipalities starting from operating railway stations. To make clear the interest of the European Community in interventions concerning these fragilities and the financial means to tackle them, reference is made to the directive "Sustainable Mobility Guide - How to finance sport, cycling and sustainable tourism with European funds" of 2018 (2).

The analysis of the connections network with a view to the development of the longitudinal links, but especially the transversal ones, would be incomplete without taking into account the orographic features of the territory. The use of traditional GIS tools has been insufficient for a quantitative analysis of the three-dimensional qualities of the case study, so it was necessary to implement ex-novo a series of tools useful for this purpose.

3. STATE OF THE ART

Territorial analyses were conducted using a GIS class software, which was used to manipulate the data provided by the Abruzzo Region database (DBTR). Additional information was integrated with a secondary database, Open Street Map (OSM) when the data in the main database were insufficient or outdated. Extracted data from the DBTR were: Digital Elevation Model (DEM), perimeters of the average dense continuous residential fabric, road, and railway network. Data extracted from OSM were: disused railway network, cycle paths, and cultural heritage.

Thanks to a Python algorithm, which works within a GIS environment, a network of slow connections from railway stations was developed. This algorithm made it possible to identify the accessibility area along the roads, having as constraints the average speed of 16 km/h (and the travel time identified in three bands, respectively 15, 25, and 35 minutes from departure. This made it possible to identify a network of roads that can be covered within certain durations. The tools for the management of the territory, generally referable to the family of GIS systems, have a wide range of uses, but are based on two-dimensional analysis. In the specific case study, it was necessary to analyze the acclivity of the land concerning road connections. An analysis of the slope was made, which has as output a raster map of the intensity and the contour lines of the territory were elaborated. Difficulties were encountered in the interaction of the slope data and roads with the raster slope data. It was possible to carry out qualitative, but not quantitative analyses.

4. SOLUTIONS

To overcome this problem, it was necessary to rely on an additional digital tool, a parametric modeler capable of handling NURBS entities. This software was combined with the basic GIS software, which managed the data import from shared databases and carried out the two-dimensional operations of vector entity modification and network analysis explained in the

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http://old2018.agenziacoesione.gov.it/it/arint/Selezione_aree_progetto/Istruttoria_e_documentazione_per_regione/Regione_Abruzzo/index.html
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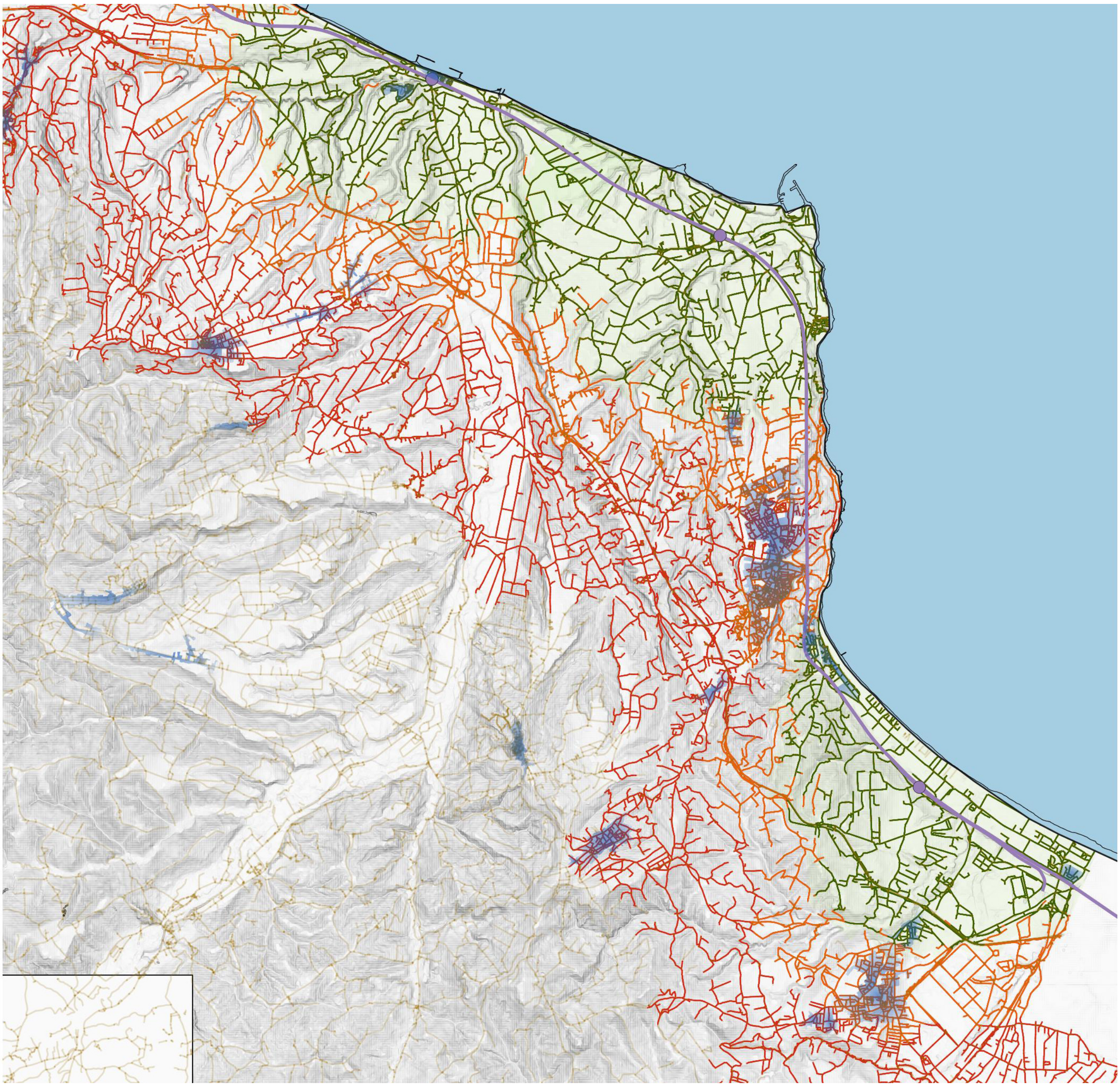

Figure 3. Soft mobility connections. Road paths originate from railway stations with cycling range of 15, 25, 35 minutes.

previous section. From the GIS it is necessary to export the vector data representing nodes and networks to the NURBS modeler. To complete the database migration work it is necessary to convert the DEM, which represents the terrain elevation raster to vector. This operation is possible through an algorithm that transforms the raster into a mesh of points. Each point belonging to this mesh is associated with a numerical height that must be transformed into a z coordinate.

The process of generating the three-dimensional model of the study area is subject to the availability of a specific type of geo-referenced data. These data are required for the terrain altimetries, which are raster files with a resolution consistent with the type of analysis required and vector files for the building and networks. These data have been firstly processed with GIS software, after with a three-dimensional NURBS modeller connected to a plugin able to manage the algorithm for Computational Design operations.

For the case study of the Trabucchi coast, the cartographic database of the Abruzzo Region was used for the availability of raster and vectorial information. To activate the process of terrain generation, the DTM digital model (with a resolution of 10x10 meters was preliminarily used) is the only one available with an adequate resolution. For the vectorial network data base the Regional Technical Cartography 2007 (CTR) was used, for the constructions the Shared Knowledge System. To assemble the entire study area (40 by 10 km) it would have been necessary to join 14 single sheets and the final model would have suffered from excessive computational slowness. It was therefore necessary to apply a GRASS algorithm to sample the DTM images, bringing the output resolution to 40x40 meters.

The DTM represents a survey of the soil surface alone without the anthropic and vegetational elements. Being a two-dimensional raster file, it was necessary to convert it into vectors in GIS environment to extract the points accompanied by their geometric coordinates, which can be read with a 3D modeler. In this way a vector shapefile is generated containing a planar grid of equidistant points with a pitch of 40 meters, each georeferenced according to the UTM-WGS84 coordinate system. In order to import this shapefile in a NURBS modeler it was necessary to design a customized Grasshopper algorithm

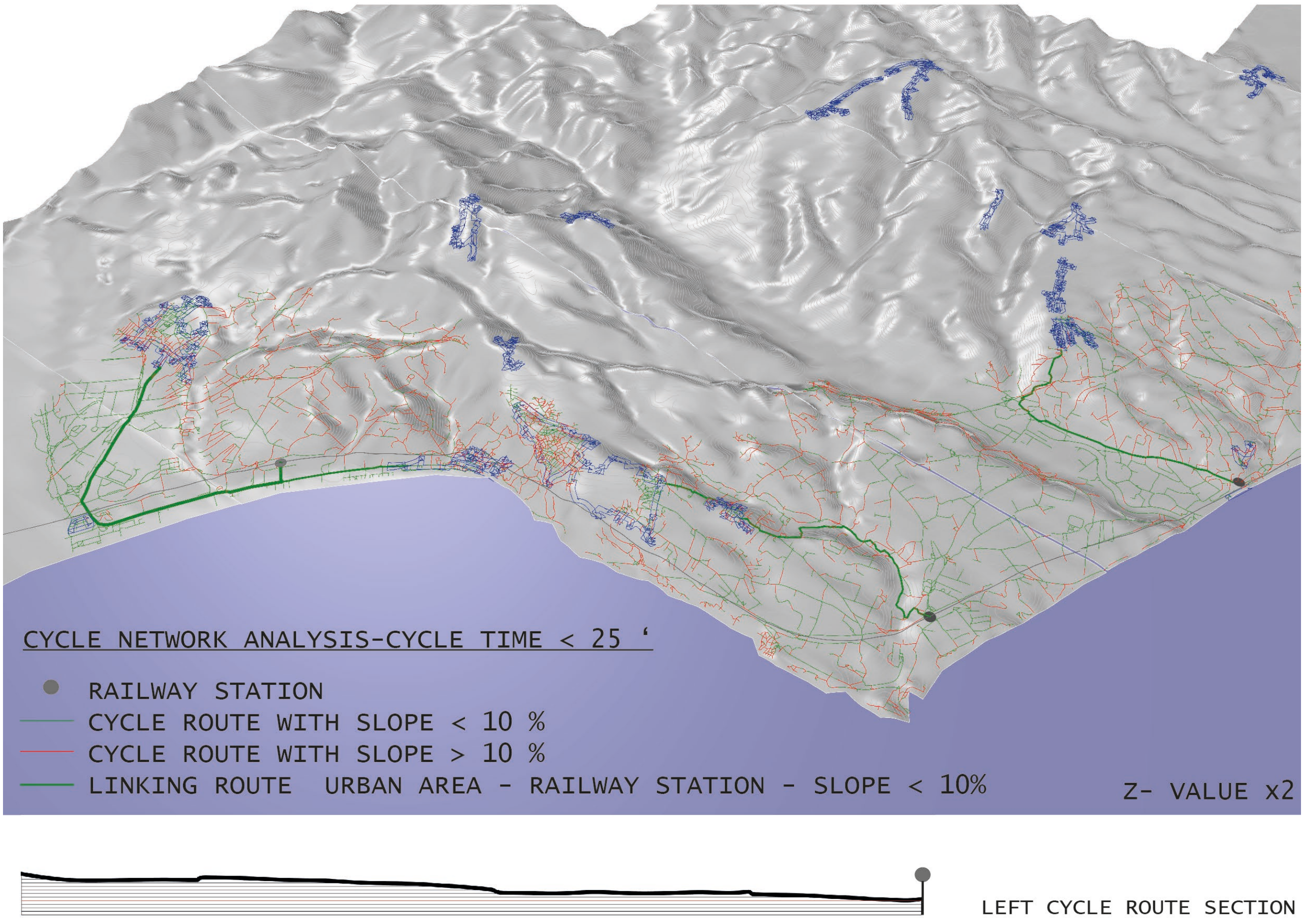

Figure 4. NURBS Model of the area. The bold green routes, which connect railway stations with hilly centers are the fastest among the paths with slope minor than 10%. The section is a rectified drawing along the left path.

that allows it to manage this type of file, usually manipulated by GIS software. The import process works, for the simplicity of algorithm construction if the points form a grid. The vector output from the raster file is often not bounded with regular edges. In this case the points that create artifacts on the edges must be removed manually. The weak point of this step is the creation of longitudinal holes when assembling together all 14 sheets of soil generated by the DTM. These holes have been manually filled with NURBS modelling; the individual sheets cannot be aligned, because they would lose their georeferencing property and it would not be possible to insert any other georeferenced elements afterwards. Once the points are imported, they are read as a list of elements distributed on a plane. In order to create the terrain surface, it was necessary to attribute to each single point the relative elevation. To do this, the numerical values of the elevations are extracted from the attributes tables - attached to the DTM file - which are assigned to the vector of displacement in positive z direction. At this step of the procedure a cloud of georeferenced points that faithfully represents a part of the territory has been obtained. To complete the surface generation, it was necessary to automatically calculate the number of points in the x and y directions. It has been chosen to extract this parameter automatically, instead of manually entering its value to increase the procedure flexibility. To calculate the number of points in the grid it is necessary to consider that they are ordered in numerical lists in which the positions are indexed. It was possible to subdivide the list into subgroups containing only the points that have the same value as x, to calculate the length of the lists. To do this the x-coordinates of each point were extracted and then stored in separate lists, and finally their mutual equality has been tested. In this way a Boolean exclusion model was defined according to which the repeated elements in the individual lists are eliminated. At this point it was possible to count the number of elements of each sublist, an indispensable parameter for the generation of the NURBS surface. The elements of the building, extracted from the Shared Knowledge System - in the Urban and Territorial Armor section of CTR- described the settlement system through the categories: Soils: these were the result of the union of Urbanized Soils (SU), i.e. the parts of cities foreseen by the P.R.G. and already implemented, and Planned Urbanized Soils (SUP), i.e. the parts of cities foreseen by the General Regulatory Plan (P.R.G.) and not implemented. The result was a series of polygons that surrounded the SU and SUP areas, after having filtered out the portions of built-up areas of a smaller size.

At this step of the dissertation, it seems useful to explain why to use such a complex procedure when it is possible to directly extrapolate contour lines from the GIS software and the mesh based DTM model. The explanation from a mathematical and geometric point of view only would require an ad-hoc work, due to the vastness of the topic. For representation and visualization, the mesh structure is more performing because the definition of simple entities such as points and polygons is simpler and there are no topological constraints except the connections between neighbouring entities. It is difficult although to make changes to the shape when the mesh model is complex because there is no global, but only local parameterization. The NURBS model, on the contrary, has an analytically defined geometry and a very simple topology, because any entity can be framed in a UV patch. This makes it much easier to write algorithms because they refer to a unique coordinated system related to the described object. Taking advantage of these special features of the NURBS system, it was possible to describe the three-dimensional model shown in figure 4, which represents the geometry of the study area with precision. The next step was to import the data from the road network, but the size of the file required a limitation to the areas surrounding the railway stations, defined as detailed in the previous section within the isochrona equal to 25 minutes of cycling at a speed of 16 km/h (Schantz, 2017). Within this selection of the road network, the slope p has been geometrically analyzed, considering that roads are composed of vectors with start and end.

$$P = |z_{endpoint} - z_{startpoint}| \, / \, lenght$$

After associating the parameter p to each single component vector, a list of vectors has been produced, whose slope is less than a given value. This set of vectors has been associated with a colour that shows only a selection of the road network of known slope. On this subnet it is possible, using an algorithm, to trace a path that connects the centers with the main nodes of the network, ensuring better accessibility.

5. CONCLUSIONS

The value of this parametric system lies in its intrinsic flexibility since once the vector network of georeferenced roads in space has been generated, it is possible to produce three-dimensional predictive analyses that are not possible in a GIS, such as inserting elements that attract routes, such as cultural elements or those peculiar to the territory. This procedure is relevant to define a strategy of design actions able to produce a more balanced use of the territory, between the coast and the hilly areas just in the background of the coastline, also considering the recent transformation of the infrastructural system. To use a parametric mapping applied to a most possible accurate three-dimensional model is essential, in order to assess the effects of the design constraints that are specific for slow mobility infrastructure. These require to be adapted precisely to the existing topography and for this, the support of a model of highest definition able to define a smooth surface is essential to support design choices, with interventions based on minimum structural and visual impact (bridges, landscaping with consistent terrain modifications). The proposed method is based on geographic and geometric information, that are useful to define a general reference system of data, necessary to define possible design options. This procedure should be implemented also with other, more qualitative oriented procedures, integrated through quality parameters and indexes defined through geographic data, interpretation of user generated contents (photographs, comment from social networks, etc), also supported by machine learning techniques (Bianchi, 2020). The research team is working in this perspective so to define a wider decisional framework that can support the decisional process in final design choices.

It is considered appropriate to develop these slow mobility strategies also in the present Covid-19 pandemic situation, in an attempt to minimize the spreading of virus infection. In these perspective, it is important to encourage forms of active and proximity tourism, also to develop an approach to mobility that allows us to rediscover in a sustainable way the areas less frequented by the mass tourism, at the same time taking into careful account their internal fragility. In short, a dual-objective strategy is confirmed: on the one hand the improve the uses of the internal areas of the Country in order to reduce present condition of social and economic marginality; on the other hand - and certainly not secondary – an attempt to consider the actual need of social distancing as an opportunity to encourage off-the-beaten-tracks tourist destinations extended on the whole territory, through means of transport that have the least impact on fragile territories and on the spread of the virus itself. This design-oriented approach to territorial strategies will produce long term, durable benefits of which both the insiders (permanent inhabitants) and the outsiders (temporary inhabitants or tourists) will benefit.

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REFERENCES

Bianchi, A., D'Uva, D., Rolando, A., Scandiffio, A., 2020, *A view from the track: measuring spatial quality of slow mobility routes: Possible integration of GIS and Machine Learning based methods*, paper in Connecting, Drawing for weaving relationships, Convegno Internazionale dei Docenti delle Discipline della Rappresentazione, Reggio Calabria, under publication, sept 2020

Burry M., 2011, *Scripting Cultures: Architectural Design and Programming* , John Wiley & Sons

Carpo, M. 2011 , *The alphabet and the algorithm* , The MIT Press, Cambridge, Massachusetts

Catmull, E. & Clark, J., 1978, *Recursively Generated B-spline Surfaces on Arbitrary Topological Meshes* , Computer Aided Design, 10(6), 350–355.

Costantini, P., 2000, *Curve and surface construction using variable degree polynomial splines* , Computer Aided Geometric Design 17, 419–446, Elsevier Science

Chan, K.L., Qin K., 2017: Biomass burning related pollution and their contributions to the local air quality in Hong Kong. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci*., XLII-2/W7,29-36.doi.org/10.5194/isprs-archives- XLII-2-W7-292017.

D'Uva, D., 2017, *Preface* in D. D'Uva. Handbook of Research. Form and Morphogenesis in Modern Architectural Contexts, IGI Global Hershey, PA, USA

Mazure, M.L., 2016, *NURBS or not NURBS?* , Comptes Rendus Machine, Volume 354, Issue 7, Pages 747-750, Elsevier

Piegl, L.A., *On NURBS: A Survey*, Jan 01, IEEE Computer Graphics and Applications, Vol. 11, No. 1, pp. 55 - 71

Schantz, P., Distance, *Duration, and Velocity in Cycle Commuting: Analyses of Relations and Determinants of Velocity,* International Journal of Environmental Research and Public Health, MDPI, 2017

Tedeschi, A., 2014, *AAD _ Algorithms-Aided Design* , Le Penseur Publisher, Brienza (Potenza), Italia

Zhong, D., Liu, J., Li, M., Hao, C., *NURBS reconstruction of digital terrain for hydropower engineering based on TIN model,* Progress in Natural Science, Vol. 18, pp. 1409-1415, 2008