Integrated Procedures for the Drawing of Linear Networks: Digital Graphic Processing of Cycling Paths

Barbara Messina, Pierpaolo D'Agostino

Abstract

The paper aims to highlight the potential and applicability of an integrated digital approach that uses the drawing as a concrete tool in support of the territorial and urban design. The integration of territorial analysis tools, together with others more traditionally used in algorithmic-generative processes, could allow to reach a global management system of data and information. In fact, territorial and urban transformations, by their nature or by virtue of their intrinsic complexity, require multi-scale control and managed on multiple interconnected levels.
Through specific digital representations, we intend to illustrate the possibility of using a GIS system, integrated with parametric modellers, for the management and verification of a series of design choices that involve urban or territorial transformations.
The proposed methodology aims to validate an analysis system applicable whenever actions are needed within an already consolidated urban space, especially to create or implement linear networks. The proposed operating procedure is therefore aimed at identifying cycle paths through a semiautomatic framework: the contribution proposes, in particular, an application on the road network of the Capaccio-Paestum Municipality, in the province of Salerno.

Keywords: digital integrated system; representation of the territory; informative database, linear routes, graphic simulations.

Introduction

The use of information systems, capable of implementing in variously algorithmic forms the interactions between the territorial and geo-topographic context, is today consolidated. In fact, the simulations generated by these systems (two-dimensional and, nowadays, more and more often three-dimensional) allow us to describe, in interactive modes, the functional conditions of project prefiguration, as well as the transformation of a context [Arctur, Zeiler 2004; Fistola 2009]. These systems are useful tools to understand and graphically describe the changes that, in specific places, result from natural or anthropic, material or immaterial events.
The geometric and topological interpretation of space, translated into a set of integrated, computerized and multi-sectoral data, allows interactive management of spatial information by virtue of which it is possible to control, process and connect all the data through appropriate digital representation systems [Du et al. 2019]. In this sense, the idea of integrating GIS software with platforms properly intended for solid and parametric-generative modelling is particularly effective, with the aim of producing infographic representations useful for the simulation of phenomena that characterize a territory [de Silva, Eglese 2000].
So, starting from some experiments, the paper highlights the potential and the applicability of this integrated digital approach, that uses drawing as a concrete tool to help in the design of the transformations of the territory and the city.

Integrated systems to represent urban and territorial phenomena

The drawing of the territory has always been a not simple challenge for man: being able to translate, into images, his morphological complexity–often due to the close interconnection between anthropic space and natural space–as well as the phenomena that occur in it, indeed requires considerable analytical and graphic skills. Then, representing the territory means understanding its relevant elements [Bonora 2012], summarized in images which, by virtue of a rigorous and essential graphic code, make immediately perceptible the aspects and specificities that distinguish it. The contribution of the Drawing's disciplines is therefore fundamental, with reference to this issue. If, in fact, the treatment of this topic "*quanto mai vasta e specialistica, necessita di un approccio multidisciplinare […] tuttavia i prodotti grafici di tali studi sono pur sempre modelli che coinvolgono l'esperto di espressione grafica di natura tecnica*" [Cardone 2015, p. 301]. This explains the great interest that the Drawing area scientific community, nationally and internationally, has been giving to this issue for some time [Chias Navarro, Papa 2019; Marotta, Novello 2015; Centofanti, Brusaporci 2011; Novello 2002]. In recent years, however, alongside more traditional research and studies–that is, oriented to the thematic reading of urban or territorial contexts [Martone 2007; Rosi 2003]–a new scientific approach has been affirmed. This one uses digital modelling and advanced graphic simulations as an irreplaceable tool for the representation of the territory, in all its aspects [Piga, Salerno 2019; Llopis Verdú, Serra Lluch, Torres Barchino 2019].
Certainly the tools available today, such as digital systems for integrated management and data representation on an urban and territorial scale, facilitate the analytical approach for reading a specific area and the phenomena connected to it [Mingucci, Moura 2013] [1], thus making it possible to elaborate, and effectively visualize, information available on several interrelated levels (fig. 1).
While, on the one hand, the use of GIS appears to be consolidated as a tool for analysing the physical and immaterial phenomena that characterize a context, the possibility of combining it with three-dimensional parametric modellers [Moura 2013] is less explored. The use of these can actually allow better management of data in all those cases in which the presence of buildings, or of design realities, intervenes in the definition and characterization of the investigated area [Yin, L. 2010].

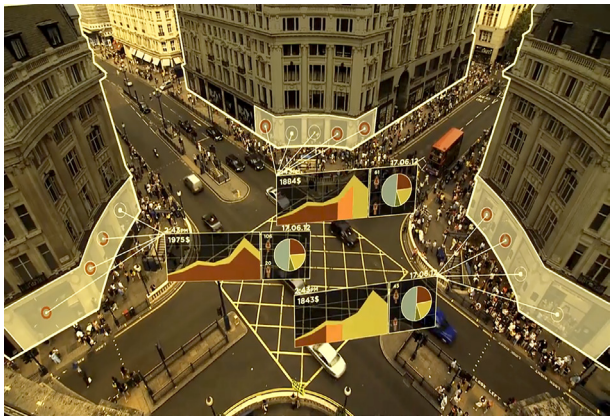

Fig. 1. Graphic-digital approach for analyzing complex realities. Example of use of the "Urban Network Analysis" toolbox, developed for the Rhinoceros software by City Form Lab. In <http://cityform.gsd.harvard.edu/videos> (accesed 2019, September 26).

The integration of these digital representation tools, therefore, perfectly meets the need to have a global data and information management system that is at the base of those projects–architectural, engineering, urban planning etc.–which, by their nature, or by virtue of their intrinsic complexity, require multi-scale control and managed on multiple interconnected levels.
In fact, the possibility of organizing and representing space geometrically and topologically in a GIS system, starting from a set of georeferenced and correlated data, acquires new and significant implications–for what concerns the analysis and design of the configured realities–if we consider the potential of three-dimensional simulation typical of parametric modelling software [Semeraro et al. 2019] [2]. Indeed, the integrated representation, thus understood, not only allows the localization of the examined phenomena, and their spatial analysis, but opens up to the possibility of foreseeing several scenarios; these ones are conceivable in the digital environment as a function of the input data, thanks to the processing of visually convincing images, that are of immediate interpretation. Precisely thanks to the visualization and virtual reproduction of space, and of phenomena that occur in it, characteristic of three-dimensional modelling software, the traditional cartographic approach, possible through GIS, evolves into a more complex pro-

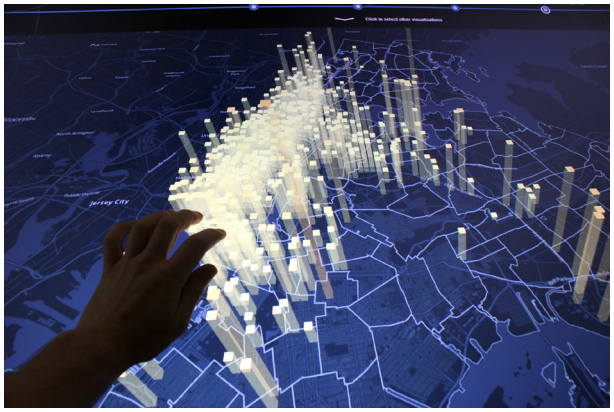

Fig. 2. Interactive representation of spatial phenomena. Visualization and analysis of data based on a "Data Collider" application, a system developed by the MIT Senseable City Lab. In <https://morphocode.com/visiting-mit-senseable-city-lab-singapore/> (accessed 2019, September 10).

cess. That is to say, a system capable of supporting–in a unitary and multidisciplinary structure–the design choices resulting from an assessment aware of the impact that a planned project can have. A system, therefore, able to suggest the most appropriate solution, from time to time, with reference to a series of transformation hypotheses conceived for the territory or the city (fig. 2).
With reference to this approach, it should first of all be noted that, although the GIS was born as a platform for data management and cartographic representation in two-dimensional form, over the years it has shown a growing interest in the aspects related to a broader interpretation of the graphically described phenomena. This conceptual evolution has increasingly required systems for the three-dimensional representation of the analysed reality. Starting therefore from the first experiments of the so-called DEM models, the territory is read and conceived no longer, and not only, for contour lines and quoted points, but in its three-dimensional structure, of which it is possible to interpret and understand characteristics and aspects whose development is not limited to the two dimensions [3]. The GIS platforms thus begin to experiment with "editing modules of the 'geographic objects "*moduli di editing degli 'oggetti geografici' assai simili a moduli CAD [...] tentando di integrare (o di far interagire) la piattaforma GIS con funzionalità di modellazione tridimensionale parametrica alla scala urbana a fini progettuali e non solo di analisi dei dati e di supporto alle decisioni*" [Muzzarelli 2016, 2].
It is a use of GIS that, overcoming the idea of a simple digital map, prefigures new perspectives of graphic and design applications, which can be summed up in the so-called 'Geodesign' [Campagna 2013; Santana, Moura 2013] (fig. 3). This is a process of land management, including its transformations, based on the combination of "*metodi, tecniche e strumenti delle scienze dell'informazione territoriale ('geo') a supporto del progetto e della pianificazione dello sviluppo fisico ('design'). Il Geodesign propone un approccio collaborativo e partecipativo integrato che parte dalla concettualizzazione del progetto e prosegue con l'analisi, la simulazione, lo sviluppo di alternative, la valutazione degli impatti e la scelta (tra le varie fasi)*" [Campagna 2014, 71].
In this direction, especially at international level, numerous studies have been carried out to test the practical applicability of integrated approaches for the representation and planning of the territory. New systems have thus emerged from the GIS, the so-called *PSS* (Planning Support Systems), the *SDSS* (Spatial Decision Support Systems) or the *PPGIS* (Planning Participation GIS). They summarize the GIS analytical capabilities with the potential of virtual simulation of 3d modelling software, in order to prefigure and verify different aspects of the planning realities, and different options that can be pursued, integrating the building modelling in the territorial context that will host it [4].
In light of these considerations, the paper, through specific digital drawings, aims to illustrate the possibility of using a GIS system, integrated with parametric 3d modelling software, for the management and verification of a series of design choices that involve transformations on an urban or territorial scale [Rybarczyk 2010]. In particular, we propose an operating methodology for the elaboration of models that record and integrate specific data to the context and to the events taken into consideration. So, these models permit us to arrive at graphic simulations that allow classifying, representing and interpreting a territorial area on the basis of a series of synchronic and diachronic spatial relationships between the anthropic, natural and environmental elements that characterize it. This is a particularly delicate problem when the area is characterized by specific environmental peculiarities, or when there is the presence of monuments, archaeological sites or other structures that impose themselves as cultural attractors, so orienting territorial transformations.

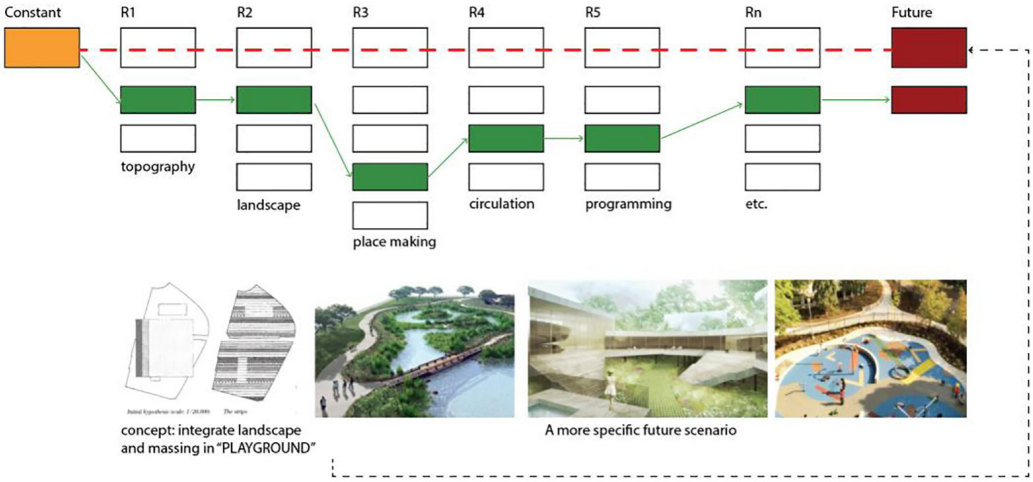

Fig. 3. An example of the application of the Geodesign logic, as a tool for participated choices in urban or territorial planning. The diagram is edited by [Wu 2018, p. 39].

Specifically, the research is addressed to the territory of Capaccio-Paestum Municipality (near Salerno) and to the coastal stretch of the provincial road that leads to it. In fact, this area is emblematic for our research, given the presence of one of the most significant archaeological sites in the world and–as better described later–of a series of other tourist attractions. Therefore, we analyse the opportunity to design cycling paths defined through digital procedures capable of 'automatically' generating a network which, according to these elements and on the basis of a series of choices and hypotheses formulated, can satisfy the needs of this context's development. Starting therefore from a project written up from the Technical department of Capaccio-Paestum Municipality, and using digital graphic elaborations generated with a specially structured GIS system, we try to verify the adequacy of urban cycle paths (designed and not yet realized) with respect to the location of a whole of attractors significant for designing them. Alternatively, we propose design hypotheses to enhance existing routes, in light of the emerged needs.
Therefore, the experimentation carried out concerned, on the one hand, the already existing network, with the aim of improving its usability by virtue of checks on specific aspects, possible thanks to infographics simulations [5]. On the other hand, we have analysed areas that are currently not involved but potentially interested in cycling: of these, we have assessed the suitability and adequacy as a function of their intrinsic and extrinsic characteristics [6]. In these cases, the spatial analysis underlying the GIS has led to outcomes and possible design solutions: of these, also through three-dimensional modelling, we have assessed the compatibility with the real situation (fig. 4). An integrated approach, therefore, that exploits the ability of parametric modelling software to interact with the data implemented in the GIS system.
So, the proposed methodology aims to validate an analysis system applicable whenever it is necessary to intervene within an already consolidated city. For example, creating or implementing a linear network, which specifically refers to cycle routes. This with the purpose of preliminarily evaluating, through graphic-analytical considerations, the compatibility of the choices made during the design phase with a series of specific urban and territorial contingencies, which must inevitably be taken into account.

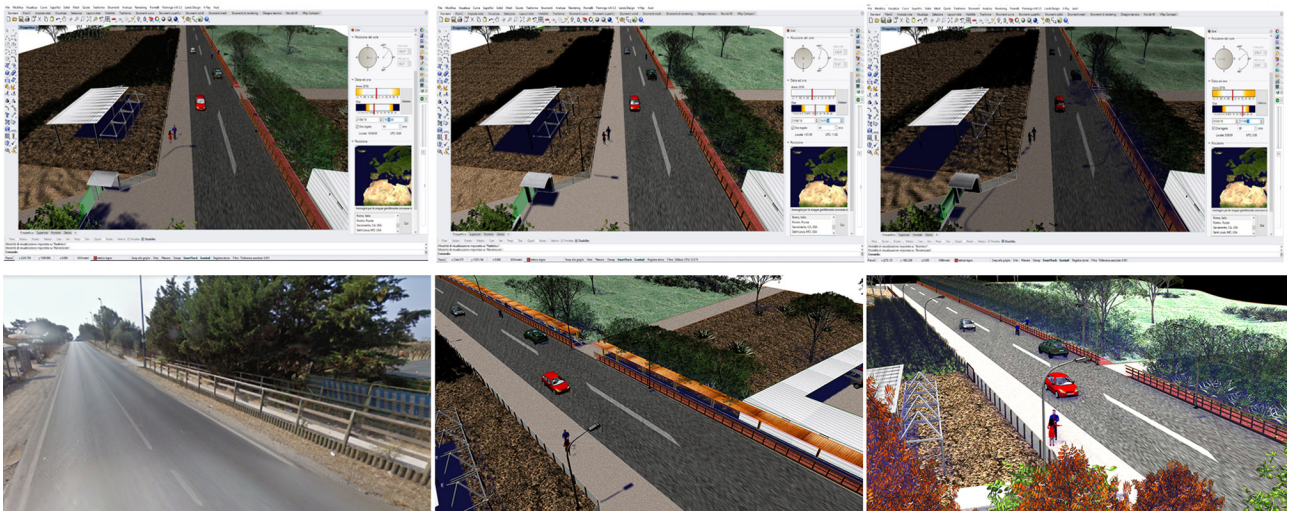

Fig. 4. Interactive simulations of the shading of the coastline cycle network, between Eboli and Capaccio-Paestum, to support future design choices (edited by Gerardo Virgilio Calzaretta; coordinator: Barbara Messina).

A practical approach: the cycle network of the Paestum coast

The context of the costal and hinterland area nearby the archaeological site of Paestum, between the Municipality that hosts it and the ones adjacent to it, therefore represents a test opportunity to check the possibility to integrate typical approaches of the representation and the information management of vast area with tools and dynamics typical of the visual scripting. In this sense, taking advantage of the possibilities that parametric modelling, in its most generalized meaning, offers thanks to increasingly specific and detailed nuances in underlying algorithmic terms, today appears to be substantially effective; especially where it is necessary to give shape to operational flows through tools that go beyond the boundaries of the aseptic and less interactive traditional programming, to develop more user friendly layouts that are no less objective and scientifically consistent than pure computing [Brown, Knopp 2008].
In the context of the elaboration of the operational procedure aimed to identifying cycle paths through a semiautomatic framework [Messina, D'Agostino 2011], assuming the reuse of the already existing road system as a starting hypothesis, it appeared first of all appropriate to vector drawing the roads belonging to the Municipality of Capaccio-Paestum, disregarding in a first phase the relative typology and, therefore, the geometric characteristics and vehicular use features. As before mentioned, in addition to the clear interest for a territory dense in singular elements suitable to a network integration proposal, the choice to experiment in this area the described methodology finds as a further motivation the executive planning developed in the last years of a cycle and pedestrian path along the coastal axis of ordinary roads. This has led to reasoning aimed to understanding about the feasibility of choices alternative to those that have already found material implementation or choices that, by integrating with the already existing ones, suggest a possible irradiation of the slow road system even beyond the coastline [Passigato et al. 2008]. In this sense, has to be reported that the idea has been to test processes that from the vast area study moved towards the creation of a database both of merely objective data and digital models. The latter, outputs of a spatial analysis, are conceived at the same time as input of further steps, at more detailed levels, to express punctual parametric generative models

intended as general cues and susceptible to become design proposals that can be refined and finalized to their engineering implementation.
In order to create the context database, useful for the identification of the existing road network suitable to host a cycle path, the workflow required a preliminary digitalization of the available cartographic repertoire which, along with the punctual data obtained with in situ survey campaigns, has contributed to the context characterization. In this sense, therefore, the entire road network has been correlated to a graph-numerical database–typically collected within an interoperable GIS oriented format–indeed related only to part of the existing road network: it was in fact imposed as a design and operational constraint the exclusion of the suburban and urban roads from the spatial elaborations, both because of their high

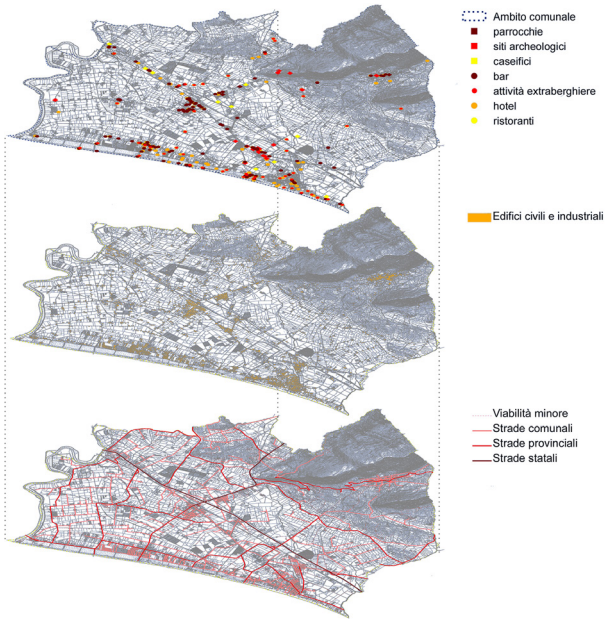

Fig. 5. The territory of Capaccio-Paestum (SA). Overlays of critical areas present in the area (viability and civil or productive settlements) related to the point attractors, interested in spatial analysis (edited by Pierpaolo D'Agostino).

design speed and their typology of road section and appurtenant areas, actually inadequate to the simultaneous presence of vehicular and cycle traffic. A similar fate for the minor roads, substantially corresponding to the penetration network to private properties, which appeared to be of little significance for the individuation of a public cycle path.
The residual road network, definitively susceptible of being processed in spatial analysis algorithms, was therefore related to the punctual database of the relevant elements of the investigated territory. The territorial density of such elements–distinguished between attractors and criticalities–has been obtained through a specific analysis of Euclidean distance. The latter was used to define the area of influence of each attractor, in other words presences–graphed as points and organized by category in cultural, receptive, productive and commercial–capable of 'magnetizing' tourist flows, and consequently of orienting the road practicability in the territory of the Municipality of Capaccio-Paestum. The results were then reported in an ad hoc raster grid in which the distances between the attractors were also calculated, assuming the 1 km threshold as a limit beyond which a user is not normally willing to walk, choosing instead other transport carriers. Outputs of this process are therefore the bands within which it may be appropriate to locate the cycling roads in order to guarantee an adequate networking to connect the elements that potentially move the main tourist flows in the area (fig. 5).
Contrasting the territorial and spatial definition of the attractor points was the identification of those intended as 'criticalities', in other words conditions, punctual or spatial, considered impassable by bicycle or because the transit is physically obstructed, both due to the presence of a series of factors that make the journey strenuous and for the riskiness of using the bicycles in relation to the geometric characteristics of the road curves. The main anthropic and natural criticalities identified and classified were the slope of the territory and the density of the urban construction. The first one, in particular, can be deduced from the orography gathered from the polygonal height field shape of altimetric interpolation, identifying the areas resulting under 15% slope, corresponding to the limit, beyond which an inexperienced cyclist isn't able to easily ride.
Similar considerations, although conducted with different spatial analysis functions, have been established as a basis

of the reasoning about the perimeter delimitation of the criticality linked to the urban construction. For this purpose, an analysis of kernel density has taken into account the distribution of buildings on the territory, allowing the identification of areas of influence in which the urban fabric tends to thicken the most. Only buildings for civil and industrial purposes have been taken into account: it is for them in fact that it was considered more likely the interference between vehicular and pedestrian roadways, given that for different categories (such as rural buildings, greenhouses, temporary buildings) there was a limited impact on the cycle path, both because of their small size, and because in general these structures are located in such a way that doesn't generate risky intersections of vehicular traffic.
The vectorization of the buffer zones, intended as enveloping bands of the critical densities, has allowed to visualize–within the roads network potentially suitable to host the cycle traffic according to the road characteristics only–all the sections in which the cycle or pedestrian transit should be interdicted. The road arcs that could be 'mapped', namely the only ones that, also in compliance with the previously described unfavourable conditions, were actually compatible with the presence of cycle paths, were therefore extrapolated.
The cycle network obtained through the described procedure was then compared with the planned network developed by the competent administrative authority, verifying its effectiveness for the good, even if not total, overlap between the output of the described operating methodology and design choice (fig. 6).
The processes here described, usually domain of GIS oriented applications, have found in the algorithmic-generative modelling tools a new operative mean for the construction of analyses that more directly, and without intermediate steps, can evolve in close connection with the related elaboration of solid models. And that is possible thanks to the management of data within workflows that directly act on the factual conditions, through their modification, thus producing the shaping and the articulation of new conformations aimed at the design intervention. In particular, these tools have demonstrated and still amply demonstrate their effectiveness even when only referring, in the need to give shape to design actions that go from the vast scale to the detailed scale, to the first dimensioning of architectural and civil elements standing on specific areas of intervention.

Fig. 6. Comparison between spatial analysis and current context. In green, the outcome of the semi-automatic analysis process carried out for the identification of possible cycle-pedestrian paths and, in red, the real structure of the existing or running tracks (edited by Pierpaolo D'Agostino).

Not only that, but the variety of operational tools provided by the most widespread parametric-generative modelling software–also in relation to the insertion of territorial and wide area data in generative processes–allows to compare and evaluate, ex ante, pros and cons of different design hypotheses. In fact, the potentialities for procedural generation of algorithmic processes is able to provide solutions that, in compliance with constraints imposed in visual scripting and with input data, provide new solutions that are difficult to prefigure and conform with a traditional process of collection of design inputs. It should also be noted that while the traditional design approach makes use of the simulation of the designed space as an evaluation tool, in a decision making process capable of providing a single solution, the new approach has definitively clarified, but not standardized, that the potential offer of data tuples can become an additional tool for decision makers [Vanky 2016]. Thus, within the current experimentation, it was assessed the viability of a further refinement of the graphic control ability deriving from the digital tools that the representation makes us avail-

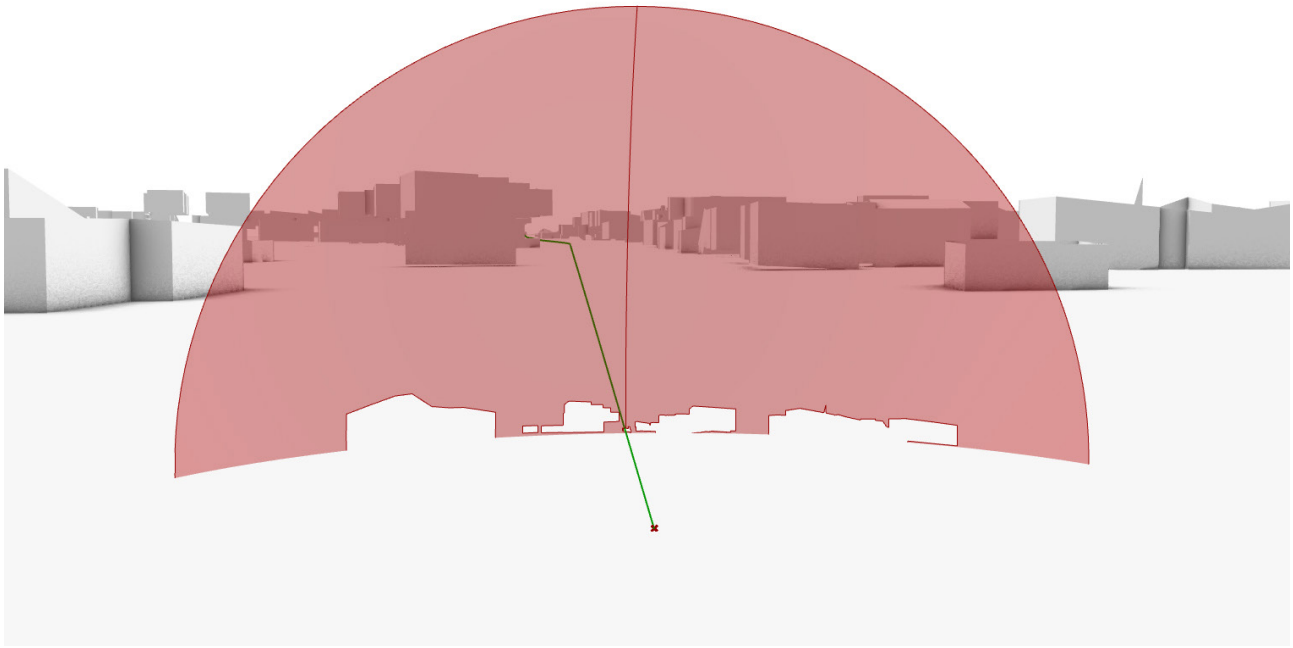

Fig. 7. Exemplification aimed at understanding the visual impact of the context around a reference point on a road layout. In green, the center line of the route; in red, the area of simulated impression of the visual field and the relative buildings offered to the perception of a user (edited by Pierpaolo D'Agostino).

able today, by entering, as an input, data relating to the visibility of road systems. A digital framework was therefore built to simulate the visual field of a virtual driver, in order to understand if and how to intervene punctually to improve conditions, before defined criticalities in the pure GIS system generated at the territorial scale, that are indeed susceptible to find a detailed solution in the modification of geometric configurations of road intersections and points of intermodal interference (figs. 7, 8).

Conclusions

The paper, focusing on the results of some experiments carried out on the Campania coast network developed between Eboli and Capaccio-Paestum, has been aimed to the implementation of a digital workflow designed to create and track, in semi-automatic and interoperable forms, linear development systems characterized by precise characteristics, also compatible with the morphological requirements of specific territorial areas.
A digital approach, therefore, able to define paths–such as for example the cycle ones, specific object of this investigation–on the basis of several data and constraints integrated as input in the digital system prepared [Cooper 2017; Terh, Cao 2018]. The outcomes of the approach described have been validated by comparing the paths already present in a specific context with those generated automatically by the system, in order to verify possible strengths and weaknesses of the various followed design methods. Digital models of virtualization defined *ad hoc* that illustrate, therefore, as a GIS can be used in the management and validation of design choices involving changes in a given context. Specifically, the suggested operational methodology reveals and

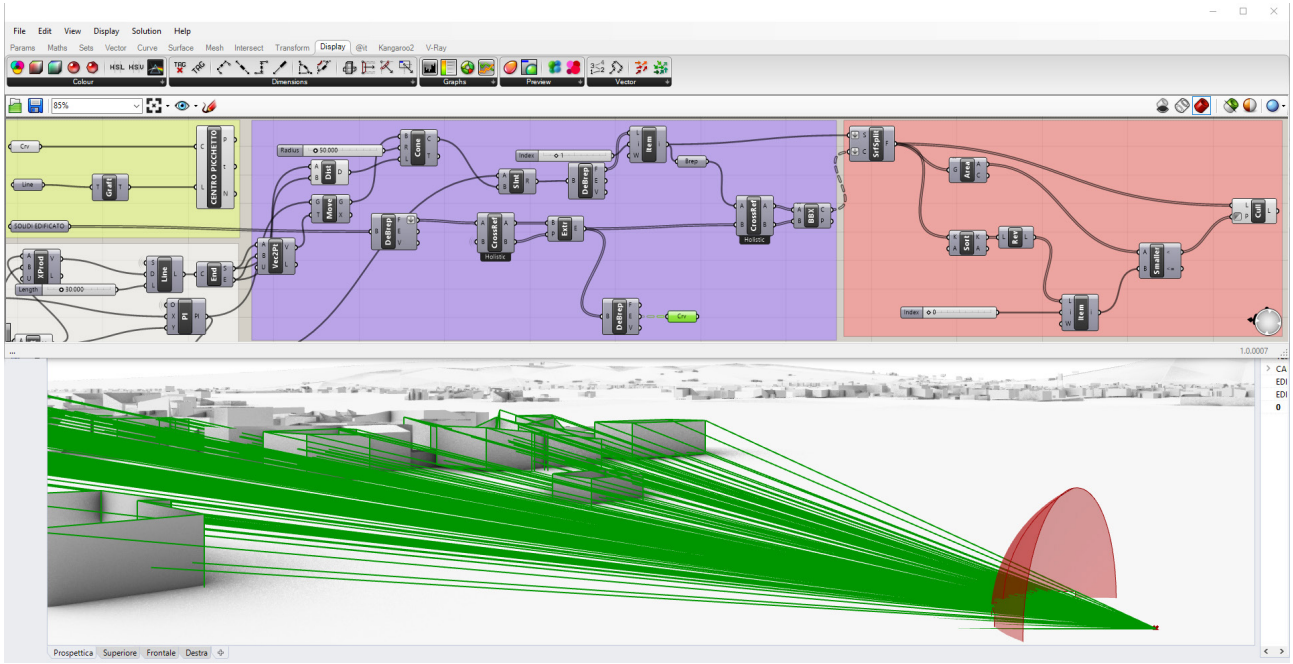

Fig. 8. Synthesis of the work interface, showing the development of the visual scripting constructed and the complete outcome of the analysis in relation to a selected point of view by way of example (edited by Pierpaolo D'Agostino).

integrates geographical information and boundary conditions deriving from various external factors, finally arriving at graphical simulations able to classifying, representing and interpreting a territorial area based on synchronic and diachronic relations between its anthropic elements, natural and environmental [Maantay, Ziegler 2006].
The work therefore aims to define a digital process imaged as a useful consultation tool in all cases where an integrated analysis of "multilevel" data is required, a support for a multi-scale design. This can modify a particular place in respect of its specificity, also with approaches that, deriving from GIS procedures, transform the relative output into analytical input for algorithmic analysis. This is particularly useful both for producing 2.5D analyses, in which the graphic descriptor is in any case a strong analysis performed in the three-dimensional domain, and in the representation of the phenomenon and of the investigated data, using visual scripting for signalling in relation between raster data and vector. The result is the cognitive expansion of conditions and phenomena through new information sets, alternative alternatives to certain spatial analysis processes [Ratti, Sommer 2012]. A mutual contribution that increases the usefulness of an interoperable work that sees, in the transition from merely modelling to the service of traditional representative dynamics, the overcoming of the cartographic production statistics useful to the final decision maker who, in the multiple offer of solutions and information, finds another easy path to the final choice.

Credits/Acknowledgements

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final dissertation (undergraduate degree in Civil Engineering, University of Salerno–speaker: Barbara Messina, co-rapporteur: Pierpaolo D'Agostino) they have contributed to the collection of data then implemented in the GIS environment and with the help of parametric modellers (Rhinoceros and its Grasshopper plug-in). The present work includes the authors' individual contributions. Specifically, Barbara Messina described the methodological approach adopted, from a theoretical point of view (in the section: Integrated systems to represent urban and territorial phenomena), while Pierpaolo D'Agostino described the operational processes (in the paragraph: A practical approach: the cycling network of the Paestum coast).

Notes

[1] The use of methodologies of landscape analysis and drawing, through integrated digital systems, appears today a priority objective at the base of the definition of the Italian professional profile of the civil and environmental engineer. In fact the new Code for public contracts and Ministerial Decree n. 560 of 1.12.2017, by the Ministry of Infrastructure and Transport, provides for "*modalità e tempi di progressiva introduzione […] dell'obbligatorietà dei metodi e degli strumenti elettronici specifici, quali quelli di modellazione per l'edilizia e le infrastrutture, nelle fasi di progettazione, costruzione e gestione delle opere e relative verifiche*". A revision of three-year and two-year graduate programs in Environmental Engineering and the Territory is underway. This change is aimed at providing knowledge and skills in the use of integrated digital modelling techniques and tools in the field of structures and infrastructures, as well as advanced experimental methods for representation and analysis of the characteristic problems of engineering for the environment and the territory.

[2] The software for parametric modelling, in general, facilitates a comparison between different design scenarios, allowing rapid changes to the objects represented, and viewable in real time on the entire project. The implementation of BIM systems for building modelling, which is based on an interrelation logic between the information database and the digital model similar to that of the GIS platforms, has contributed to making the management process of territorial or urban contexts more effective. This made it possible, in each phase (planning, execution, maintenance), wide reading and checking of the interventions designed in them.

[3] On the evolution of GIS systems, in terms of technological progress and graphic potential, much has been debated in recent years, both nationally and internationally. On this topic, we highlight, among others, the studies of Arctur and Zeiler [Arctur, Zeiler 2004], of Picon and Ratti [Picon, Ratti 2019], as well as of Muzzarelli [Muzzarelli 2016].

[4] On the diffusion and the experiments in this direction see the studies of Geertman and Stillwell [Gertman, Stillwell 2003], of Campagna [Campagna 2014], and of Di Cesare [Di Cesare 2016].

[5] Digital modelling has allowed, for example, to verify with interactive simulations which sections of the existing cycle paths require shading systems and, at the same time, to compare multiple design solutions.
In the example in figure 4 two of the three options considered are illustrated: the first consisting in the arrangement of sunshade systems, the second in the planting of suitable tree species in order to project shade on the road, the third in the deviation of the cycle path into the existing pine forest. The graphic simulations have allowed, in all cases, to verify ex ante the hypotheses formulated, thus allowing the designers a more informed choice.

[6] With specific reference to the investigated area, the spatial analysis–carried out graphically in both two-dimensional and three-dimensional form–was aimed at identifying areas suitable for hosting cycle paths. The conditions at the base of the graphic considerations were the presence of tourist "attractors" and the absence of significant "criticalities".
For example, for the coastal area next to the beaches, depending on the number of tourists present here in the different periods of the year, the existence or not of excessive traffic on potentially suitable routes has been verified. More precisely, identified as the fulcrums of the spatial analysis the groups of dwellings present in the coastline, of which a part exclusively destined to summer tourism, first of all we have estimated the visitors' presences in the various months, in order to evaluate the trend of the expected population density during the year. In particular, we have represented the areas of "influence" such as circumferences–of variable extension with the variation of the population density–with the center placed in correspondence of the main housing aggregates and radius equal to the numerical datum associated to the density. The areas–derived from the overlap of two or more circumferences–have therefore been identified as critical because they are too trafficked and, therefore, not suitable for a cycle crossing.

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