ANALYTIC NETWORK PROCESS (ANP) AND VISUALIZATION OF SPATIAL DATA: THE USE OF DYNAMIC MAPS IN TERRITORIAL TRANSFORMATION PROCESSES.

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ABSTRACT

Multiple Criteria Decision Analysis (MCDA) is generally used to support planning and decision making processes, but the sharing of information can often be limited by two main factors. Firstly many users have difficulties in reading output data, especially if these are tables, matrixes or databases. Secondly, many actors means also different discipline, knowledge, interests and, overall, different languages. The paper shows the contribution that the visualization of spatial data can give to the Analytic Network Process (ANP) [Saaty, 2005, Saaty T. L., Vargas L. G., 2006].
This research approaches to visualization in order to create a common grammar among involved actors and a shared basis for generating discussions. Thus, the use of an interactive visualization tool can support MCDA in showing results and, in particular, evaluating alternative options, improving the information sharing among professionals [Van den Brink, 2007; MacEachren, 2004]. To face these issues, a new study has been started for implementing an ongoing research on a modelling system which is able to visualize various kind of data in real time. This modelling system is based on McNeel's "Rhinoceros" software and its free plug-in "Grasshopper" and works on generative and parametric features applied to datasets. The starting point of the work is an application to a German section of Corridor 24, Genoa-Rotterdam, part of an Interreg IVB NEW Project, called "Code24". The goal of the ANP application is to rank three scenarios of the improvement of "Betuwe ljine" railway connecting Oberhausen to the Dutch borders. The first results of this research (obtained by an academic internal application), once improved, will be used in several focus groups with the main stakeholders of these territorial transformation projects.

Keywords: Geo-visualization, ANP, Dynamic Maps, Parametric and Generative Modelling, Rhinoceros, Grasshopper

1. INTRODUCTION

The use of ANP in real decision-making arenas to study alternative planning solutions showed some areas for potential improvement. First of all, the assignment of weights to clusters and nodes requested by ANP could create misunderstandings due to a lack in non-expert users' ability to comprehend their meaning. Secondly, a more perceptive grammar can generate a common basis for sharing information and allowing discussions. Indexes, weights and rankings from ANP must be object of discussion as well as their results. They are not part of a black box [Latour, 1987] but need to be assessed by DMs. Thirdly, the large quantities of data to manage during decision-making process highlighted the necessity to filter items in order to better identify and isolate the most interesting.

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To face these questions, a new study has been started for implementing an ongoing research on a modelling system which visualizes in real time various kind of data. Information and Communication Technologies (ICT) provides nowadays a large amount and typologies of tools, mostly underused, which offer the possibility to visualize numerous data and relate them to specific features. Thus, no other new tool has been created, but existing software have been investigated in order to find the best fitting to multidisciplinary processes.
This modelling system is based on McNeel's "Rhinoceros" software and its plug-in "Grasshopper", and works on generative and parametric features applied to datasets. Although this plug-in has been created for supporting industrial production and generative architectures, this research aims to its use for supporting decision making processes on wide areas. In particular, the Grasshopper plug-in offers new opportunities to planning. It implements generative and parametric functions [Masala, 2005; Caneparo 2007], allows the system to work in real time, can relate shapes with behavioural formulas and supports large databases from Microsoft Excel. It can also be additionally implemented with free plug-ins and scripts in Visual Basic language, which are available on the Web.
After the introduction, the rest of the paper is organized as follows. Section 2 illustrates questions to be solved to merge the ANP technique and three-dimensional model technology. Section 3 describes the application to the case study, with the structure of the ANP complex network integrated with the spatial model, showing the maps obtained for each subnet. Sections 4 concludes the paper with a discussion of the results obtained from the tools merging .

2. COMBINING ANP WITH GEO-VISUALIZATION

To achieve the merging between the ANP technique and three-dimensional model technology, three key issues were to be solved:

- the translation of qualitative information into spatial form;
- the building of a framework of weighted relations among the spatial items which represent the nodes, clusters and subnets of ANP structure;
- the interaction between model and users.

During planning processes, many aspects of decision-making are referred to specific areas and have a well defined spatial form and localization. These elements and their influence on land can be easily represented in a three-dimensional model. They can be a new road or a residential zone as well as the geometric features included in GIS data. Other questions have not this direct connection with a spatial form, as economic or social issues, and have to find a way to be represented. To face this problem, geo-visualization offers a lot of techniques [Tufte, 2001] which make use of symbolic features applied on spatial areas. Thus each element of BOCR analysis has been translated into a weighted map describing its own suitability on land. Since not all questions have a direct form of representation, mathematical formulas, also very complex, can be applied to visualize their spatial behaviors. In this way the influence of an element on space shape can be determined with specific equations deriving from different expertise.
ANP works on weights assigned to relations among nodes, clusters and subnets, therefore this modeling system must be implemented to generate spatial forms on the basis of weighted relations among different components. For this reason, the same framework of relations and weights among ANP elements has been reproduced to set up the 3D model.
One map is created for every ANP node, where the node is represented by a symbolic mode of visualization. Each map changes according to the weights assigned to its relation with the other nodes, clusters and scenarios. This structure of relations results very complex, but allows to visualize the spatial effect of each node. Then, the modeling system can provide a map for each level of ANP structure, allowing both their overlapping and comparison.
In this system, users can interact with the model, which can visually update its form on the basis of DMs' input. If during focus groups, weights as well as mathematical formulas of spatial behaviors are changed, the system update in real time its outputs, offering an important tool for clarifying the cause-effect relations between decisions and spatial results.

3. APPLICATION TO THE STUDY CASE

3.1 Presentation of the case

ANP and Geo-visualization tools are here applied to study a German section of Corridor 24, Genoa-Rotterdam. The German railway system in the Ruhr Region needs to be implemented to upgrade the connectivity between the German city of Oberhausen and the Dutch borders. In the framework of Corridor 24 development, the changes in the transport system across the borders between Netherlands and Germany imply a new spatial configuration for the areas of Northern West Germany. Therefore, the case study analyzes various possibilities for upgrading the connectivity of the areas. The spatial dimension is very large to study at once, then the analysis will be conducted through proposing the same scenarios for different smaller areas to related focus groups. This paper shows the study concerning the area of Wesel, in which are involved three main partners of the "Code24 project": SiTI - Politecnico di Torino (Italy), ETH of Zurich (CH), University of Duisburg-Essen (D) and Universiteit of Utrecht (NL). Three alternatives have been considered in applying ANP (table 1).

Table 1: Alternatives for improving the rail line in the Ruhr Region

Alternatives	**Characteristics**
Option 0	Improvement of existing "Betuwe" rail line: no new railway is created. Only railway signaling is increased in order to improve the number of trains.
Option 1	Addiction of a third track in the German stretch of Betuwe railway line, which runs through many towns, making necessary the creation of noise barriers for the passage of high speed and the elimination of many grade crossings.
Option 2	Freight transports leave the railway passing by Venlo and use the Betuwe rail line until Wesel, where an existing but unused by-pass has to be restored in order to connect Wesel with both its port on Rhein and Oberhausen through the countryside.

3.2 Structure of the BOCR model

According to the literature review and problem analysis (Bottero, Lami, Lombardi, 2008), the decision problem has been divided into four clusters (environmental aspects, economic aspects, transport aspects and urban planning aspects) that have been organized according to the BOCR model.

To obtain spatial visualizations of BOCR, a model in Grasshopper was built on the basis of drawings, databases and GIS data as infrastructures, built areas and geographical features. The model consists in the creation of the relationships among all the elements of drawing in order to reproduce the ANP structure as a kind of “flow chart”. It determinates the rules of parametric model and assign a spatial behaviour to each node. This passage presents many questions to solve, which involves the knowledge of several expertise. In this test case, the main task is not to obtain a totally working model but to investigate how the merging of ANP with this modeling system can really support participative and collaborative processes. Therefore, even if the modeling system can make use of complex mathematical formulas, this initial phase of research employs only simple rules given by the symbolic representation of phenomena, as censed by an internal survey (table 2).

Table 2: Clusters and nodes and symbolic modes of visualization used in the test case

BOCR	**Cluster**	**Elements**	**Map**
Benefits	Environment	Reduction in traffic emissions in urban areas	Linear buffer along main roads
	Economic	Improving the economic role of the Region	Constant value
		Creation of employments directly related to the transport improvement	Constant value
	Transport	Increase in frequency of connection	Radial buffer on railway stations
		Creation of a freight hub, by intersecting rail, road and river transport, connected to Wesel port	Land use

		Increase in the capacity of freight transport	Linear buffer along main roads and railways
Opportunities	Economic	Possible creation of new jobs indirectly related to the improvement of the regional transport system	Constant value
		More trade	Constant value
	Transport	Possible river connections to Berlin for freight transport	Linear buffer along main waterways and radial buffer centred on port
		Increase in the capacity of people transport	Radial buffer on railway stations
	Urban planning	Promotion of new forms of settlement along the track enhancement	Linear buffer along railways
		Elimination of grade crossings	Radial buffer on grade crossings
Costs	Economic	Investment costs	Constant value
		Acquisition/expropriation of areas for the insertion of new track	Linear buffer along railways
	Environment	Noise and vibration impacts	Linear buffer along railways and main roads
	Urban planning	Trains visual impact	Linear buffer along railways
		Possible creation of big barriers in landscape	Linear buffer along railways
Risks	Economic	Possible extensions of implementation time due to the conflicts arising with the local population	Constant value
		Decrease in property values	Linear buffer along railways
	Environment	Soil consumption	Linear buffer along railways

ANP questions find the weight of nodes' importance on a numerical scale. By default, the model is set to represent no preference among alternative options. Each map changes according to the weights assigned to its relation with the other nodes, clusters and scenarios.
To simplify this test case, a symbolic map acting on a 50m x 50m grid has been assigned to each node of ANP framework. The nodes with an identified spatial behaviour generate an influence depending on distance, while "not spatial" nodes (as the economic ones) produce constant maps which lay on the whole area. This test case makes use of two kinds of maps: a bi-dimensional one in which color gradient is the indicator of each node weight and importance; and a 3D visualization based on the extrusion of symbolic maps. The resulting representation is a deformation of land, acting in real time, that create a kind of 3D diagram according with weights assigned to each node. Other visualizations are possible combining 3d models, colors, buffer areas and more to increase the number of ways for communicating information.

3.3 Resulting visualizations

For this first application, visualizations have been used to show the ANP results referring to subnets and scenarios. The displaying of BOCR provided a support for users in reading the behaviors and tendencies of each scenarios. In particular, it shows to be effective when used with a slicing plane which cut away areas with lowest heights and display outputs with more potential.
The visualization of each subnet describes the effects on space and highlights the specifics of each scenario. As example, here is shown the visualization of benefits subnet (fig. 1), corresponding to the weighted matrix (tab. 3). The heavy weight of economic cluster , represented by constant values, is visible in high level difference between scenarios. Scenario 1 is the more useful to improve people mobility: the maps of stations, which symbolize the increasing in frequency connection, and road network, representing the reduction of traffic emission, have more weights than others one. In the meanwhile, scenario 2 shows his “attitude” to trade and economic development due to the importance of logistic HUB creation.

Table 3. Weighted Supermatrix (Benefits)

		Alternatives			Economic Aspects		Environmental Aspects	Transport Aspects	
		Option 0	Option 1	Option 2	Employments	Economic Role	Reduction traffic emission	Freight hub	Frequency connections
Alternatives	Option 0	0,000	0,000	0,000	0,055	0,055	0,072	0,077	0,200
	Option 1	0,000	0,000	0,000	0,290	0,154	0,279	0,231	0,200
	Option 2	0,000	0,000	0,000	0,655	0,290	0,650	0,692	0,600
Economic Aspects	Employments	0,123	0,185	0,123	0,000	0,000	0,000	0,000	0,000
	Economic Role	0,616	0,555	0,616	0,000	0,000	0,000	0,000	0,000
Environmental Aspects	Reduction traffic emission	0,094	0,094	0,094	0,000	0,000	0,000	0,000	0,000
Transport Aspects	Freight hub	0,011	0,015	0,124	0,000	0,000	0,000	0,000	0,000
	Frequency connections	0,078	0,076	0,018	0,000	0,000	0,000	0,000	0,000

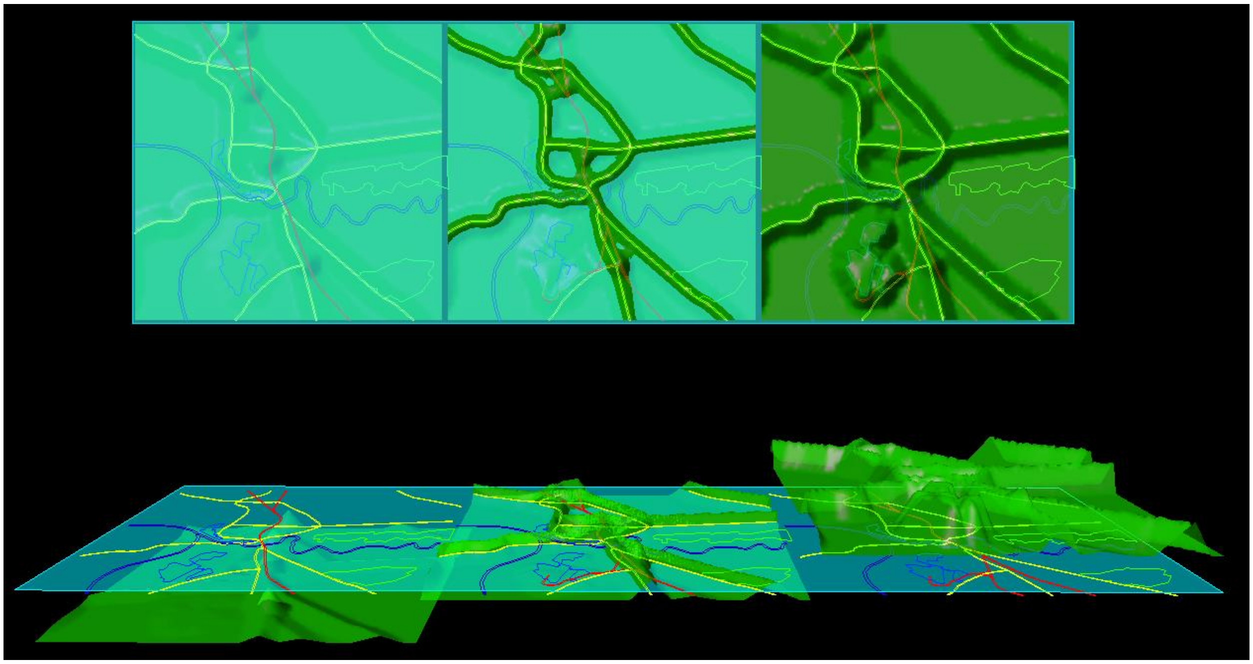

Fig. 1 Visualisation of Benefits by 3D diagrams: scenarios comparison.

The same tendencies of benefits maps are visible in the subnet of opportunities. The elimination of grade crossing in scenario 1 and the river connection in scenario 2 confirm that first one is more indicated for people mobility while the second one for economic development. In costs subnet scenario 1 results more expensive than scenario 2. The scenario 0 has a smaller investment cost but it is hardly characterized by the lack of noise barriers that determinates in the visualization a sequence of picks along the railway due to train visual and vibration impacts. Also in the risks subnet, scenario 0 is strongly influenced by the lack of barriers. In scenarios 1 and 2 the extension of implementation time determinates the increase of risks, but in the second, the use of an old track and the bypass of urban area could reduce the possibility of local conflicts.

The modeling system provides also the possibility to compare scenarios using different combined views of subnets. For instance, switching on benefits and costs maps(fig. 2), it is visible that the lack of barriers in scenario 0 creates an overcoming of benefits by costs. In scenario 1 the benefits are larger than costs, but there's a clear conflict along the rail tracks as consequence of weight of urban planning cluster. Only in scenario 2 benefits completely overcome costs.

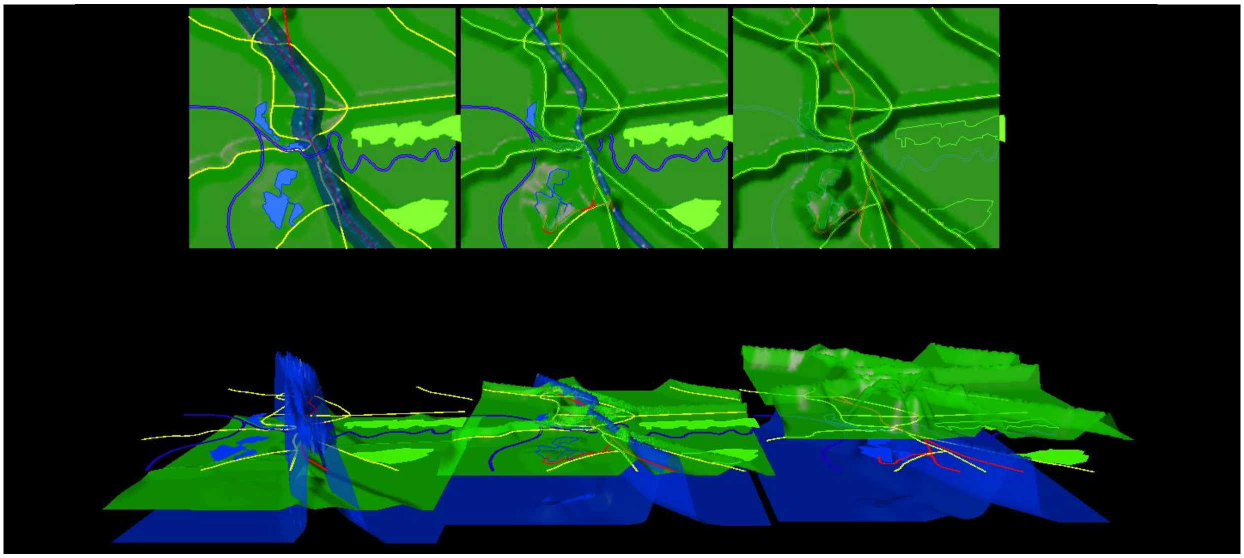

Fig.2 Comparison of the visualization of Benefits and Costs

4. CONCLUSION

This paper presents the possibility to integrate modeling system for spatial visualization to the Analytic Network Process with a new approach, without new software, but with a more creative way to use the existing ones. The paper tries to make a further step to facilitate the DM to handle all the data collected during territorial transformation processes using specific 2D and 3D maps in order to analyze the perceived influences among the different elements of the decisional problem.

The results obtained are sufficiently promising, even if many question remain to solve. The spatial visualization of the ANP application is coherent with input choices; parametric and generative features of the modeling system for symbolic spatial visualization well fit with the use of weights in ANP. The weights assigned to the elements of BOCR analysis were related to spatial forms, represented through dynamic maps. This means that the spatial model correlates numerical and qualitative values with their effects on spatial form providing a 3D spatial localization of planning choices. It constantly updates its form showing in this way the effects that weights assigned in ANP have on spatial form. In particular, the possibility to change the weights and relations among BOCR elements makes this tool an interesting support for generating discussion in multi-actor processes, as the territorial and urban ones.

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