International Journal of Architecture, Engineering and Construction
Vol 3, No 4, December 2014, 247-261

Landscape and Environmental Impact Evaluation of Roundabouts

Elisabetta Ginelli[1], Lorenzo Mussone[1,*], Gian Domenico Riva[2] and Marco Trabucchi[3]

[1] Politecnico di Milano, Department of Architecture, Built Environment and Construction Engineering
Via Bonardi, 9 20133, Milano, Italy

[2] Laboratory of Architecture, Via Fratelli Galliari, 26 24047 Treviglio (BG), Italy

[3] Technical Society of Building Design, Via Paglia, 10 24122 Bergamo, Italy

Abstract: The interest of researchers and practitioners on roundabout solutions has been growing increasingly in the last decades. The often large areas occupied by this type of intersections require special attention on the use of ground and the preservation of the natural, environmental and architectural heritage. This aim also presents the opportunity for evaluating their impact on the landscape and environment. The paper proposes a new method developed for roundabout evaluation (but generalizable to other infrastructures and fields) borrowed from building technology and based on the needs, requirements and performance expected from an object rather than on prescriptions for and descriptions of its dimensions and quality. Applications on two roundabouts are presented in order to highlight practical developments. Their final evaluation sheets are presented and through them it is relatively easy to single out the problems and drawbacks of the roundabouts from the landscape point of view.

Keywords: Landscape, environment, roundabouts, design, impact evaluation

DOI: 10.7492/IJAEC.2014.020

1 INTRODUCTION

In the two last decades all over the world roundabouts have been a frequent solution for solving road intersections involving areas that are generally wider than in signalized, stop and give way intersections (Curti et al. 2008). Technical literature on design and building roundabouts from a vehicular traffic point of view is more or less comprehensive both for the European and for the overseas scenario (FHWA 2000; NCHRP 2007; Pochowski and Myers 2010; Abdel-Aty and Hosny 1997; Taekratok 2000; Queensland Government 2002; Austroads 1993; CETUR 1988; CERTU 1998; CERTU 1999; SETRA 1997; Pompidor and Fain 2004; Züst 2003). Some authors (Mandavilli et al. 2008)) have already pointed out the potential role of roundabout in reducing atmospheric pollution produced by vehicles, others (Daniels et al. 2011) studied safety concerns for different types of road users. Other problems arise with roundabout insertion in urban and rural environments. For example the inner part of roundabouts (the central island) is often used, especially in urban environments, for the insertion of monuments, trees and advertising boards; large areas must be dedicated for building roundabout, and so on. All these facts imply a considerable impact of roundabouts on the landscape and environment that should be evaluated from the point of view of design requirements.

To face the task of the environmental integration of road infrastructures, as for any object, it is opportune to start from carefully reading the guidelines proposed by the European Landscape Convention, Florence in 2000 (Council of Europe 2000). The first article of these guidelines provides a definition of landscape, policy, quality requirements, preservation, management and planning. It extends the definition of landscape and modifies the ways of possible intervention not only to some protected areas but to a whole region taking into consideration environmental, ecological, cultural, perceptual, political and economic points of view.

The present paper, in dealing with the environment, points to a series of unavoidable considerations lead-

*Corresponding author, Email: mussone@polimi.it

ing to the extension of the concept of landscape, to eco-compatibility, to the need to reduce energy consumption and to the necessity for a continual check of environmental quality.

The multi-disciplinary capacity necessary to face the environmental question can be best achieved by using an integrated technological approach.

The evaluation of road intersection performance, like any other road infrastructures, should take into consideration the impact on the landscape and environment which, by now, cannot be ignored. This has stimulated research to find new paradigms of analysis. Particularly in the building process an evaluation method has been developed that is not based on prescriptive norms but on fulfillment of requirements relating to specific user needs stated in the next chapter.

The method proposed in the paper for roundabout evaluation is a synthesis of the guide-lines prepared for the Italian Ministry of University and Research (Ginelli et al. 2010). It is based on the same principles as those developed in the building process and specifically adapted to the consideration of roundabouts. This has led to the definition of the characteristic functional elements of a roundabout (called a "Functional Island"), and all the needs and requirements that describe the expected working of roundabouts. A survey of the real characteristics of a roundabout is the first step of the method and specific sheets are provided to help in this task. All possible needs and requirements and their correlations are previously defined in other tables and the second step requires recognition of those that are really applicable to the roundabout under study. The final step is the completion of the evaluation sheet.

2 THE REFERENCE THEORY: AN APPROACH BASED ON THE DEFINITION OF NEEDS AND PERFORMANCE

2.1 Principles

In general, in order to face a problem using an approach based on needs and performance means, by and large, to assume that the quality of a generic object depends on the fulfillment of certain needs, either implicit or explicit, established by those who have to use it (Becker 2008; Szigeti and Davis 2005).

To fulfill these specific needs, requirements or expectations consistently to the principles and modalities of this approach, represents the aim to be reached or the answers that a specific object must give.

Such a method is different from the conventional prescriptive-descriptive type approach where the guarantee of the final result depends on prescriptions about the nature and dimensions of the object. In fact, it achieves the desired quality independently of the materials and techniques used and thus the concept of needs, requirements and performance are fundamental as explained in the following paragraphs.

A norm based on these above-mentioned assumptions is qualitative and aims at defining and controlling quality by establishing a precise link between the performance of an object and the needs of the users to whom it is destined. This concept is general and applicable to all road infrastructures and therefore also to roundabout intersections.

In the architectonic and building field the components of needs, requirements and performance become the cornerstones of the method and the technical specifics become quantifiable determiners of quality.

Historically, the norm is aimed at the regulation of objects; its purpose is to describe the physical characteristics that objects must have on the basis of past building experience and then of consolidated know-how and state of the art building. The norm states its own evaluation and directive character through an explicit description of objects and it makes prescriptive technical and technological choices and, consequently, also defines its figurative character, until the middle of the twentieth century. This substantially descriptive character is characterized by how and what made a technical element durable, safe, stable, etc., so that it is suitable for the purpose for which it was made, in the light of previous experience.

The traditional norm which is descriptive and object oriented, operates by establishing "how an object should be" with an aim (not explicitly) of guaranteeing users.

Since the second half of the twentieth century the building sector has been characterized by a rapid growth in technological innovations. The shift of interest towards the qualitative character of a work leads to a consciousness that it is necessary to analyze and evaluate the environmental conditions which are representative of human needs rather than the physical and building characteristics of technical elements.

New materials are continually introduced into the building process; components are used instead of semi-finished products; approaches to design are substantially modified and require specific game rules.

The industrialization of building changes the industrial production of building components and the characteristics of new materials, of new production systems, and hence of building itself, making the traditional methods obsolete.

The conceptual framework of a norm evolves and, indeed, changes from "regressive" (limiting the freedom of design choices and therefore of action) to "progressive" (allowing expressive freedom within a range of action that is controlled differently and solicits action).

With a performance approach the norm becomes less rigid and no longer focuses on a declared description of objects but on checking performance; in other words it focuses on the behavior of the used object through a continuous dialectic between demand and supply.

In this sense, the designer does not have to define performance whether indirectly or implicitly controllable by a regulatory design, but he can, through the verification of the performance itself, adopt solutions, materials and new forms without obeying to closed "a priori" rules.

All physical descriptive information about an object becomes knowledge and analysis of demands and needs that, properly coded, become requirements or, in other words, components capable of singling out the conditions of fulfillment of a building system in certain conditions of use and solicitation.

The performance-requirement approach states and justifies the independence from the technological choice by establishing the performance of a product that represents a sufficient guarantee for the user. Hence, it defines the performance levels of a product with respect to a set of requirements that can be schematically listed as safety, comfort, adequacy and environmental conservation and management.

Therefore the performance norm describes the objectives to be reached as regards performance independently from the technology used: this means to open design possibilities towards research into and the use of new materials and technologies.

The quality of objects or artifacts is generally the goal to aim at on the basis of specific boundary conditions, both material and immaterial, and also historical. This clarification is necessary because quality is a relative, not an absolute value, an answer is qualitatively proper for every specific need provided that it is analyzed and fulfilled with sufficient performance.

The three components, needs, requirements and performance which, together with quality, make up the concept of the building process are the basis of the need-performance approach which recognizes the fundamental role of the user who becomes the starting point of a design through a definition of his needs.

2.2 Basic Definitions

The UNI 10838 standard (UNI 1999) (the Italian ISO), "Terminology for users, performances, quality and building process", explains the above mentioned concepts by means of the following definitions:

- i need: what is necessary for the proper development of a user activity (such as acts or actions carried out by the final user of the building for which a space must be singled out) or of a technological function (such as the function of a technical element the progress of which is necessary to obtain performance);
- ii requirement: translation of a need into components capable of singling out the conditions of fulfillment by a building system (considered like a structured set of spatial and technical elements, internal or external, concerning the building, characterized by their functions and by their reciprocal relations) or by its spatial or technical parts, in some conditions of use or solicitation. Requirements are normally classified into: functional-spatial, environmental, technological, technical, operational, for durability, for maintenance;
- iii building performance: the actual behavior of the building system or of its parts in real conditions of use and solicitation. Building performances are normally classified in environmental or technological performance;
- iv building process: an organized sequence of phases starting from the acknowledgment of needs of users of a building object and leading to their fulfillment through design, production and management of the same object;
- v building quality: considered as the whole of the properties and characteristics of the building system or of its parts that give them the capability of fulfilling explicit or implicit needs through performance. Building quality is normally defined as: functional-spatial, environmental, technological, technical, operational, for use and for maintenance.

Some needs refer to practical aspects and others are more linked to the emotive sphere of possible users of an object; others can derive from uses and behaviors related to certain geographical or cultural areas.

Needs to be fulfilled can also be referred to a single user or to a group of users. In some cases questions can be asked at the same time both for a single user and for more or less numerous groups. In any case the objects under consideration must be capable of fulfilling the needs of users as defined through their specific requirements.

Therefore products can guarantee demand requirements only if their performance is satisfactory when they are being used. Products must be capable of satisfying those requirements and meeting needs previously established but they must also be capable of referring to the specific context in which they operate.

It is clear that the input of the whole process and, therefore, the needs established by users, is fundamental. Hence, many simultaneous and scalar needs must find a comprehensive answer in a series of requirements that in a synergic way satisfy a global performance. Finally "quality" in building can be defined as the measure in which they correspond to the level of performance of objects according to the requirements that have motivated their devising, namely, design, production, choice and execution and that continue to justify their existence.

3 METHOD

3.1 Information Structure

The proposed method aims at defining criteria in order to set up an information structure based on the needs and performance approach capable of evaluating the impact on the landscape and environment of roundabouts. How this aim is reached is schematically depicted in Figure 1. It is made up of four main phases each concerning the analyses and specifications of roundabout characteristics the results of which are the input for the evaluation of the correlation between the classes of needs, of performance, of fundamental components and, lastly, of requirement verification, as explained in the following sections.

In order to outline this method, a systematic overview of roundabouts built in Europe, from the landscape and environmental point of view, was worked out. Countries with a longer experience in this kind of intersection such as the UK, France, Germany, Spain, The Netherlands and Switzerland, as well as Italy, were analyzed.

3.2 Parameters Set up and Informational Structure

After the survey depicted in 3.1 possible parameters for evaluating a "functional island" have been singled out. They can be divided into the following classes: needs, requirements and performance; environmental integration and the requirements of eco-compatibility (Figure 2).

The analysis of these evaluation parameters makes it possible to define correlations between the class of needs and that of environmental requirements.

The next step concerned the definition of elements useful for describing the roundabout: specifications, description, survey of geometry and materials; supports for evaluation; cartography and norms; photographic documentation; design work.

Then by coupling the elements of a "functional island" and the correlations between the class of needs and that of environmental requirements, the performance to be guaranteed by the functional components of the roundabout can be defined.

Therefore, landscape and environmental integration is defined on the basis of the level of fidelity to the defined requirements for all correlations between the class of needs and that of environmental requirements.

The above mentioned principles must be compared with required performance (and then with related needs), according to variable parameters (of context, landscape and traffic) and non variable parameters (objects and regulatory). In particular the following parameters are singled out with their subsets:

i The class of needs uses:
  (a) adequacy,
  (b) safety,
  (c) landscape and environmental qualifications,
  (d) management;

ii The class of requirements:
  (a) accessibility,
  (b) risk perception,
  (c) landscape and environmental compatibility,
  (d) maintainability;

iii The components of a "functional island" ("type"):
  (a) central island,
  (b) circulatory roadway,
  (c) entry links;

iv The variable parameters:
  (a) context - category of landscape,
  (b) categories of traffic (users, vehicles),
  (c) volume of traffic (for vehicles, motorcycles, cycles, pedestrians);

v The non variable parameters:

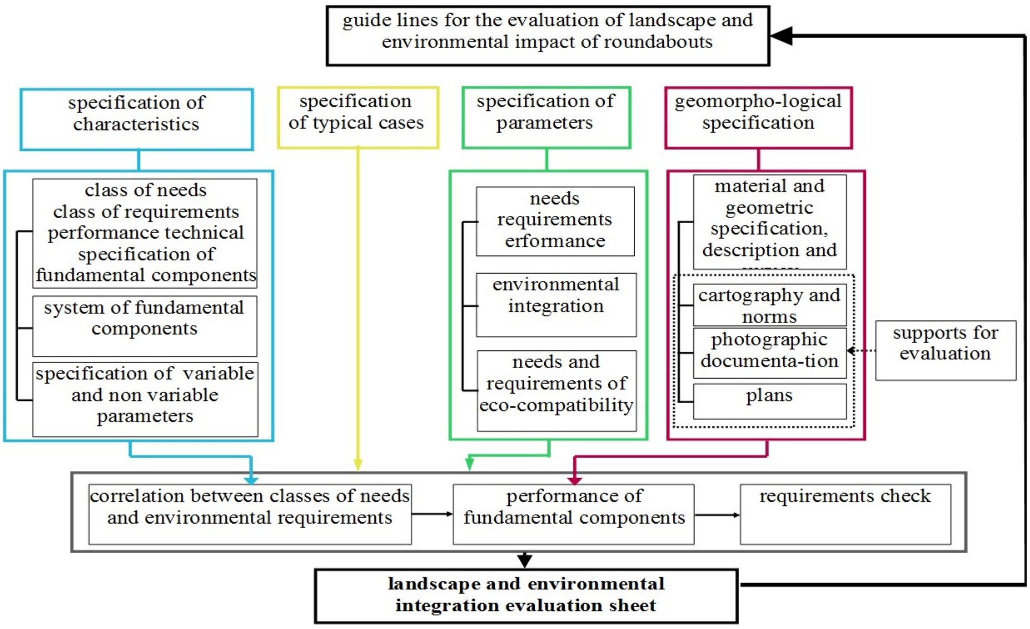

Figure 1. Flow chart of the methodological steps in order to build the evaluation sheet

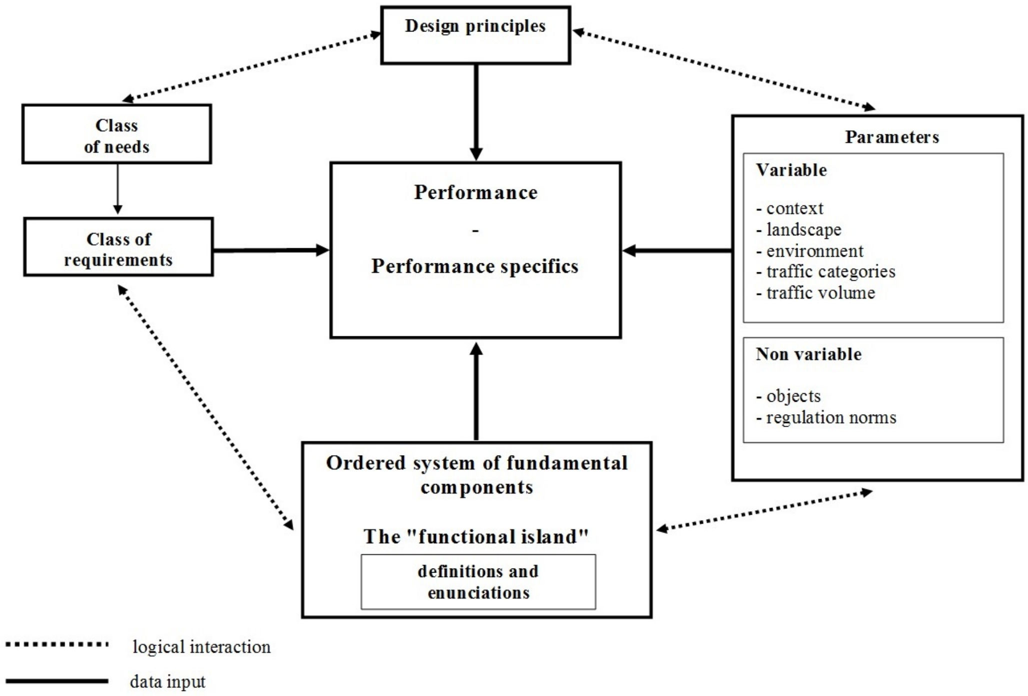

Figure 2. The methodological scheme: criteria for an informational structure of roundabout intersections

(a) objects (supplementary systems, signs, technical and underground utilities),
(b) regulation norms.

As has already been mentioned a list of significant European roundabouts from a landscape and environmental point of view was carried out by applying evaluative and selective criteria reported on a sheet based on the fundamental components of the "functional island".

Collected information refers mainly to:

i context,
ii planimetric conformation,
iii dimensions,
iv layers/materials,
v supplies.

4 THE METHODOLOGICAL SCHEME FOR THE APPLICATION OF THEORY

A standard roundabout (called a "functional island") has been outlined by defining a "type" of roundabout according to its fundamental components (non variable parameters) identified after an in-depth analysis of existing European roundabouts. These components are: the central island, the circulatory roadway and the entry links (Figure 3).

Then classes of needs to be linked to them have been defined by describing user needs: adequacy, safety, landscape and environmental qualification and management are the priority ones (in Table 2, the complete list is reported). To each of them can be associated further components with their own requirements in rela-

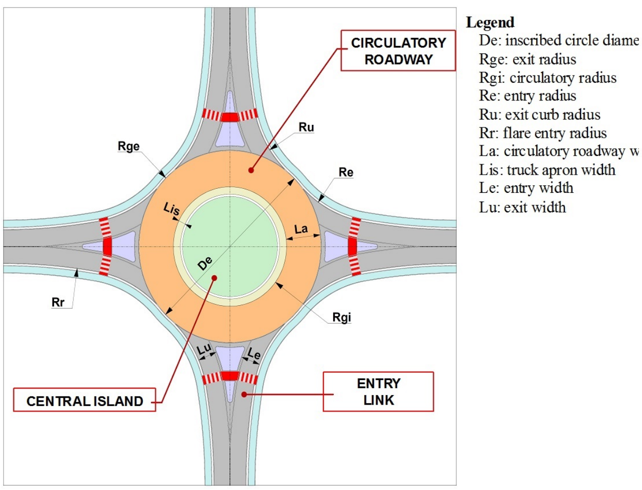

Figure 3. The basic components of a "functional island"

tion to the technological performance of the "functional island" components. Through the combined analysis of required performance and of variable and non variable parameters, the fundamental components of a "functional island" type are further worked out by defining exactly the characteristics they have to be fulfilled in order to satisfy the design requirements while, at the same time, paying particular attention to an acceptable landscape and environmental integration.

As regards the characteristics of the objects of a "functional island" as a whole, the elements taken into consideration are: inscribed circle diameter, exit radius, circulatory radius, exit curb radius, flare entry radius, circulatory roadway width, truck apron width, entry width, and exit width.

As regards the central island, the circulatory roadway and the entry links, they are listed in Table 1.

4.1 Needs in Roundabout Use, Requirements and Performance

The "functional island" type (based on geometrical and functional characteristics of roundabouts) must be related to the class of needs (based on user needs).

The class of needs is defined through the analysis of the class of requirements and each requirement performance must be defined for each fundamental component of the "functional island" type by using specific methods.

The functional breaking down of each fundamental component of the "functional island" type, the identification of the context where the roundabout is placed, landscape classification and traffic analysis, represent the basic steps necessary for singling out the needs, requirements and performance of "functional islands".

Although many tables were prepared to define analytically the characteristics of the "functional island" to help the drawing up of the final evaluation sheet, only the table of possible needs, environmental requirements and performance is reported here in Table 2.

Other tables refer to:

- i list of all functional elements of fundamental components (central island, circulatory roadway, entry links) in which all components are described according to their functional features;
- ii variable parameters (context, classification of landscape, classes of traffic, volume of traffic) and non variable ones (supplementary systems);
- iii for each class of needs, the detailed list of needs; for each need the respective parameters for controlling needs, requirements and technological performance;
- iv the critical aspects which constitute a priority to be met through specific actions as a function of variable parameters to be taken into account;
- v for every phase of the life cycle, the eco-compatibility needs to be achieved through the respective requirements by using proper materials, products and technical tools;
- vi the relationship between classes of requirements and environmental requirements obtained by comparison of evaluation parameters.

Each environmental requirement of the "functional island" components is related to a class of needs producing a double entry matrix.

Other sheets are prepared for surveying the elements of the "functional island" useful for the evaluation of landscape integration. In particular all the elements necessary for identifying the intersection: localization and context, planimetric and altimetric conformation, dimensions, layers and materials, supplies.

Table 1. Characteristics of elements for the three main components of a "functional island" type

Component	Parameter	Value
Central Island	Morphology	Round; elliptic; "oblong" or irregular
	Conformation	With apron; raised
	Characterizing Elements	Type of finish; paved; green; presence of natural elements; presence of artificial elements
	Size	Diameter; truck apron width
Circulatory Roadway	Morphology	Round; elliptic; "oblong" or irregular
	Alignment with respect to link axes	Central position; not aligned
	Size	Width; inscribed circle diameter of roundabout; exit radius; circulatory radius; angle between consecutive legs
	Traffic categories	Vehicles; pedestrians; animals
Entry Links	Constituent elements	Lane; quay; splitter islands; sidewalks; bicycle path; crosswalks
	Size	Width; entry radius; exit radius; flare entry radius
	Traffic categories	Vehicles; pedestrians; animals

Table 2. The "Functional Island" ("type"): Fundamental Components, possible classes of needs and environmental requirements

Classes of needs	Needs	Environmental requirements
Use adequacy	Geometrical	Accessibility
		Forms of control of geometric spaces
		Convenience of use
		Convenience of movement and travel
		Convenience of maintenance
		Comprehensibility of the manoeuvre and the distance
		Easy orientation
	Materials	Roughness control
	Efficiency	Constant performance in operation
Safety	Geometrical	Safety of movement in space
	Towards Atmospheric Agents	
	Mechanical	Safety of the use of space
		Safety of movement in space
	Electric	Safety of use of service supply
	Fire	Fire prevention
		Opportunities and quick response and evacuation
	Hygienic	Septic control of harmful biological cultures
		Control of aseptic conditions (attention to cleanliness, disinfection and disinfestations)
		Internal environmental protection
		External environmental protection
		Accessibility
Appearance	Morphological-geometric	Interventions for controlling geometric spaces
	Chromatic	Control of colour present in the area
Integration		Attention to technological integration
		Easy to equip
Management		Maintainability
		Easy to repair
		Replaceability
Comfort	Anthropological-dynamic	Limitation of vibrations in the environment
	Olfactory	Limitation of smell concentration
	Acoustic	Control of environmental noise
	Optical luminous	Control of environmental brightness
	Visual	
Environmental Integration	Ground	Optimization of ground use
	Subsoil	Preservation of chemical and physical characteristics
	Air	Limitation of air pollution
		Reduction of existing air pollution
		Minimization of incidents of potential leakage of gaseous pollutants
	Energy	Reduction of energy consumption
	Climate	Improvement of local microclimate
	Waters Surface	Maintenance and enhancement of surface water
	Hydro-Geo-morphological Structure	No alteration of the existing hydraulic set-up
	Noise	Limitation of noise pollution
		Knowledge of noise levels generated by traffic
		Reduction of existing noise
	Nature and Biodiversity	Protection qualitatively and quantitatively of existing natural areas and biodiversity
		Inclusion of new vegetation in artificial areas
	Health and Wellbeing	Safeguard of drivers
		Safeguard of pedestrians and cyclists
	Landscape	Minimization of the alteration of valuable landscapes in terms of aesthetic or cultural considerations
		No introduction of new elements into the landscape
		Negative aesthetic perception
		Creation of new, quality landscapes
	Cultural Heritage	No deletion and / or damage and / or compromise of the territorial historical, cultural and monumental heritage
		Promotion of the existing cultural heritage
	Spatial Planning	No elimination or alteration and / or movement of existing works with territorial functions
		Limitation of the use of valuable spatial areas
		Improvement of levels and distribution of traffic

4.2 Evaluation of Impacts and the Evaluation Sheet

Table 3 fixes the performance to be guaranteed by all the functional components and checks the necessary requirements by crossing the elements of the "functional island" with the correlations between the class of needs and that of environmental requirements. In particular it evaluates landscape and environmental integration on the level of fidelity to the requirements for all possible correlations between the class of needs and that of environmental requirements and represents the final evaluation sheet.

The survey of all elements (by using different and appropriate techniques) and a profound knowledge of

Table 3. The "Functional Island" ("type"): Fundamental Components, possible classes of needs and environmental requirements

Site:

Class of needs and environmental requirements		"'Performance of Fundamental components (Central island, circulatory roadway, entry links)"	"Fulfillment check"
USE ADEQUACY FR	GEOMETRICAL GE		
The set of conditions in which users (drivers and pedestrians) can use the ąřFunctional Islandąś properly	Accessibility (capacity of central islands and outer spaces, if used by the public, of being easily reachable and usable) FR-GE 1	Structures and manufactured articles, built to make easier access to the central island (slip roads, underpasses, overpasses, retaining structures, preservation works), must be built with a view to respecting or improving preexisting landscape elements FR-GE 1.1	Yes/No/NA
		When the central island is open to people (such as a square or park) all facilities inserted for user needs must be built with a view to respecting or improving preexisting landscape elements FR-GE 1.2	Yes/No/NA
		Designs must insert outer spaces for others uses (such as buffer areas, panoramic views, pedestrian and cyclist paths) in order to improve, from the user point of view, the relation between the ąřFunctional Islandąś and the surrounding landscape, with specific attention to the presence of natural or architectural landscape and environmental elements FR-GE 1.3	Yes/No/NA
	Control of shapes and spaces, of planes and slopes (longitudinal and cross-sectional) in circulatory areas and in the central island FR-GE 2	Shapes and spaces must have such planimetric and altimetric characteristics that highlight spots of interest, in order to consolidate fine views or hide deteriorated areas or elements of high negative impact FR-GE 2.1	Yes/No/NA
	Ease of use (ease of direction, comfort and understanding of paths and possible maneuvers) FR-GE 3	Insertion of arboreal, shrubby and herbaceous vegetation in order to guide drivers through vegetal signals FR-GE 3.1	Yes/No/NA
		Shapes and spaces must have planimetric and altimetric characteristics that respect the existing landscape FR-GE 3.2	Yes/No/NA
	Ease of maintenance (presence of suitable spaces for maintenance operations) FR-GE 4	Shapes and spaces for maintenance must have planimetric and altimetric characteristics that respect the existing landscape FR-GE 4.1	Yes/No/NA
	MATERIALS MA		
	Control of pavement roughness (control of irregularity and roughness of pavement surfaces) FR-MA 1	Use of a limited number of materials, harmonious and of local provenience, in order to build a recognizable structure and a unique language FR-MA 1.1	Yes/No/NA
		Use of materials with a dialectic relationship to the surroundings, with balanced textures and colors within the context of the landscape FR-MA 1.2	Yes/No/NA
APPEARANCE AS	MORPHOLOGICAL-GEOMETRIC AS-MG		
Set of conditions regarding the perceived use: for the reciprocal relations between the ąřfunctional island" and the landscape	Control of geometric forms of spaces and supplies AS-MG 1	Pinpoint within the perception area that is visible from the ąřfunctional islandąś towards the landscape, any extraneous elements that obstruct noteworthy sights and suggest possible interventions for safeguarding or reconstructing panoramic cones AS-MG 1.1	Yes/No/NA
		Pinpoint the influence area (panoramic cone) that is visible from the landscape towards the ąřfunctional islandąś in order to form an opinion concerning the visual impact brought about by the intervention AS-MG 1.2	Yes/No/NA
		Natural and/or artificial features (trees, waterways, street furniture, lighting, posters, safety barriers, etc.) should be introduced with a view to respecting or improving optical visuals and cones as far as the existing landscape is concerned AS-MG 1.3	Yes/No/NA
		ąřFunctional islandsąś to be constructed near a built-up area should be designed as far as possible as recognizable entries to the urban center and should respect the existing landscape AS-MG 1.4	Yes/No/NA
		The morphologic unity of the artifacts should be sought through the type of elements and recurring motifs (curbs, retaining walls, safety and sound-proof barriers) AS-MG 1.5	Yes/No/NA
		Excessive heights should be avoided for retaining walls and impact mitigation systems should be planned using vegetation screens that fit coherently into the surrounding landscape AS-MG 1.6	Yes/No/NA
		When there are no existing notable elements, works can be carried out that become potential landmarks of the surrounding landscape as well as points of reference that are significant in themselves. AS-MG 1.7	Yes/No/NA
	CHROMATIC AS-CR		
	Control of colors present in all spaces (control of color contrasts) AS-CR 1	Materials used should be in dialectic relation to those present, in harmony with the layout and colors of the surrounding landscape AS-CR 1.1	Yes/No/NA
	Maintenance of colors present in all spaces (do not dirty easily and are resistant to the washing away of the materials used in working conditions) AS-CR 2	Materials should be accurately chosen in such a way that they are not subject to rapid deterioration that could modify the perception of the sites AS-CR 2.1	Yes/No/NA
	MATERIALS AS-MA		
	Control of materials and textures present in all spaces AS-MA 1	Propose a synthesis of the materials used, possibly in a limited number, consistent with each other and, if possible, culled from local sources in order to create a recognizable and coherent structure. AS-MA 1.1	Yes/No/NA
		Materials used should be in dialectic relation to those present, in harmony with the layout and colors of the surrounding landscape AS-MA 1.2	Yes/No/NA
ENVIRONMENTAL PROTECTION SA	GROUND SA-SU		
Set of conditions for the maintenance and improvement of the states of over-lying systems of which the 'functional island" is part	Optimization of ground use SA-SU 1	Enhance the surroundings of the roundabout by inserting them into the roundabout design in accordance with the instruments of urban planning SA-SU 1.1	Yes/No/NA
		Develop the work using an integrated plan that takes into account the surrounding areas and gives preference to natural supplies SA-SU 1.2	Yes/No/NA
		Assemble technical plants into a single technical and inspection compartment using a minimum of excessive elements SA-SU 1.3	Yes/No/NA
		Insert vegetation into any marginal areas by including in the plan of the ąřfunctional islandąś the surrounding fields which would, otherwise, be cut off by the construction of the ąřfunctional islandąś SA-SU 1.4	Yes/No/NA
	SUBSOIL SA-SO		
	Preservation of chemical and physical characteristics SA-SO 1	Assemble technical plants into a single technical and inspection compartment using a minimum of points of access SA-SO 1.1	Yes/No/NA
	AIR SA-AR		
	Limitation to air pollution	Give preference to the use of materials and components with a reduced quantity of equivalent CO2 emissions from primary non-renewable energy used for extraction, production and transport, in harmony with the layout and colors of the surrounding landscape SA-AR 1.1	Yes/No/NA

Table 3. The "Functional Island" ("type"): Fundamental Components, possible classes of needs and environmental requirements (continued)

Class of needs and environmental requirements	"'Performance of Fundamental components (Central island, circulatory roadway, entry links)"	"Fulfillment check"
SA-AR 1		
Reduction of existing air pollution	Any barriers for absorbing pollutants should be made of sturdy vegetation as an active element in the reduction of atmospheric pollution SA-AR 2.1	Yes/No/NA
SA-AR 2		
WATERS SURFACE SA-AS		
Maintenance and enhancement of surface water SA-AS 1	Take into account the reclamation of environmental water courses by integrating into planned interventions the restoration or installation of embankment vegetation in order to maintain environmental continuity SA-AS 1.1	Yes/No/NA
HYDRO-GEOMORPHOLOGICAL STRUCTURE SA-AI		
No alteration of the existing hydraulic set-up SA-AI 1	Any works relating to natural water flow that are necessary in order not to modify existing hydraulic plants should be integrated according to naturalistic engineering techniques for a correct collocation in the landscape-environment SA-AI 1.1	Yes/No/NA
NATURE AND BIODIVERSITY SA-NB		
Protection of existing natural areas and their biodiversity	Limit to strictly necessary areas the insertion of courses of water or humid environments in order to guarantee the functionality and physical continuity of ecological elements and of biodiversity SA-NB 1.1	Yes/No/NA
SA-NB 1	Resolve the directional routes and crossing points of animals and strengthen weak spots in existing vegetation SA-NB 1.2	Yes/No/NA
	The instruments for making the ąŕfunctional islandąś suitable for the crossing of wildlife (ramps, underpasses, overpasses, retaining works, protection works, etc.) should be made respecting and/or improving the visual aspect in respect of the existing landscape SA-NB 1.3	Yes/No/NA
Increase vegetation in artificial areas SA-NB 2	Give preference to indigenous vegetation and a layout consistent with the surrounding environment by using compatible plants SA-NB 2.1	Yes/No/NA
	Scale splitter islands with a view to inserting vegetation SA-NB 2.2	Yes/No/NA
	Introduce arboreal, shrubby and herbaceous flora into the central island where such flora is envisaged SA-NB 2.	Yes/No/NA
	Introduce arboreal, shrubby and herbaceous flora along the lateral spaces where such flora is envisaged SA-NB 2.4	Yes/No/NA
LANDSCAPE SA-PA		
Minimization of the alteration of landscapes valuable for aesthetic or cultural features	Design the altimetric and planimetric geometry respecting the transformations consolidated by the surrounding landscape and existing morphologies SA-PA 1.1	Yes/No/NA
SA-PA 1	Where alterations are unavoidable in surrounding areas, mitigate them as far as possible SA-PA 1.2	Yes/No/NA
Introduction of no new elements in the landscape with negative aesthetic perceptions SA-PA 2	Adapt the physical and performance features of works to the character and values of the surrounding landscape SA-PA 2.1	Yes/No/NA
	Control the scale ratio between new works and existing natural and artificial elements SA-PA 2.2	Yes/No/NA
	Smooth out any differences between the ąŕfunctional islandąś and the context, by integrating the building work into the landscape and minimizing its artificial impact by means of the following: escarpments that reflect, as far as possible, the natural profile of the ground, moulded and with rounded forms that allow for new planting; stabilize the earth by means of naturalistic engineering; make use of local arboreal plants and shrubs, placing them in such a way that they are integrated into the surrounding landscape SA-PA 2.3	Yes/No/NA
Creation of new elements with a landscape quality SA-PA 3	Define significant visual cones by identifying the principal existing visual elements that are of value in the landscape SA-PA 3.1	Yes/No/NA
	Redevelop the landscape of surrounding areas (appurtenant areas, buffer zones, the surrounding territory) where they have been neglected SA-PA 3.2	Yes/No/NA
	When there are scars on the territorial network (ecological, visual-perceptive, historical, cultural and functional) intervention is necessary in order to recompose its integrity SA-PA 3.3	Yes/No/NA
	Planting arrangements (destined to enhance the landscape by becoming an integral part of it; to protect artefacts; to safeguard users and reduce the impact on the environment) should be considered as a whole, designed in an organic way and related also to interventions designed to mitigate the impact, to provide compensation and, when necessary, to work on landscape redevelopment SA-PA 3.4	Yes/No/NA
	Resolve situations in danger of deterioration, potentially related to residual areas, by inserting them into appurtenant areas and giving them a qualitative worth SA-PA 3.5	Yes/No/NA
CULTURAL HERITAGE SA-BC		
No deletion and / or damage and / or compromise of the territorial meaning of historical, cultural and monumental heritages SA-BC 1	In areas of naturalistic, cultural and landscape relevance, conserve and enhance their qualities SA-BC 1.1	Yes/No/NA
Promotion of existing cultural heritages SA-BC 2	Protect and enhance historical artefacts and their contexts SA-BC 2.1	Yes/No/NA
	Define significant visual cones by identifying the principal visual elements of value in the landscape SA-BC 2.2	Yes/No/NA
	Introduce arboreal, shrubby and herbaceous flora to highlight places of interest and to enhance viewpoints and to hide any degraded areas or high impact negative elements SA-BC 2.3	Yes/No/NA
SPATIAL PLANNING SA-AT		
No elimination or alteration and / or movement of existing works with territorial functions SA-AT 1	Adopt mitigating planning solutions with a view to not compromising or modifying existing geo-morphological elements and rebuild, if necessary, areas of particular landscape and environmental sensitivity SA-AT 1.1	Yes/No/NA
Limitation of valuable spatial areas consumption SA-AT 2	Give preference to criteria of intervention that allow the preservation of the continuity of the territory as regards green urban and territorial networks maintaining the perception of existing settlements and monuments SA-AT 2.1	Yes/No/NA
Requirement Code	Final remarks to integrate the performance evaluation	

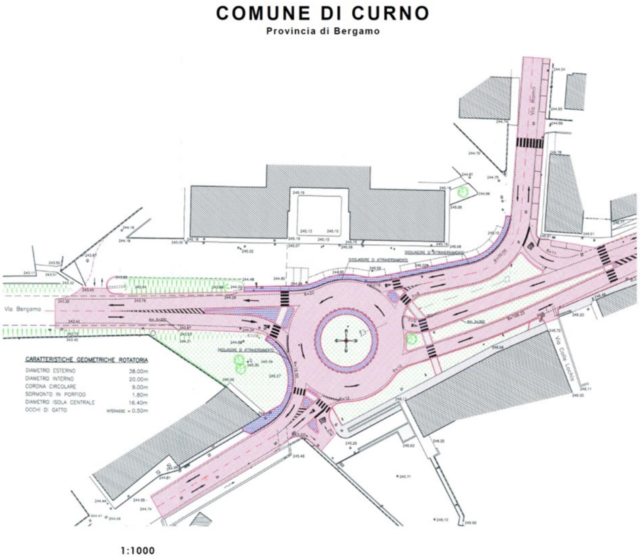

Figure 4. Layout of the roundabout of case study A (city of Curno)

Figure 5. Aerial view of the roundabout of case study A (city of Curno)

places thanks to the numerous tables make it possible to achieve the results.

The methodology also proposes a final table that sums up on the roundabout planimetry the positive or negative evaluation of each component.

5 APPLICATION TO TWO CASE STUDIES

In this section the evaluations of two case studies according to the developed method is presented. These two case studies refer to two roundabouts with different characteristics both as regards their form and their urban context in such a way as to represent a significant though not comprehensive sample of possible roundabout building:

i The first one, case study A, is in the municipality of Curno (BG, Italy) and is in an urban context (Figure 4 and Figure 5);

ii The second one, case study B, is in the municipality of Ponte San Pietro (BG, Italy) and is in a rural context characterized by an environmental landscape of significant importance (Figure 7 and Figure 8).

In order to develop the evaluation a set of information about territorial planning, conditions of things, roundabout design is necessary. Documentation collected for the analyses is the following:

i Territorial landscape regional plan;

ii Territorial plan of provincial coordination;
iii General town plan & aero-photogrammetric maps;
iv Photographic documentation of conditions of things;
v Executive design (available only for case study A).

The analysis firstly aims at selecting from the complete evaluation sheet present in the guide lines (Ginelli et al. 2010) the only items with a negative result for which an intervention should be necessary. The results of this task is reported in Table 4 and Table 5, and then on the photographic documentation as described in the following paragraphs (Figure 6 and Figure 9).

It must be underlined that, in general, other specific users (such as blind pedestrians) or other traffic conditions (and therefore atmospheric and acoustic pollution) can be considered if necessary, this implies simply the definition of further needs and requirements.

5.1 Case Study A (Urban Environment)

This roundabout is located in an urban environment (Figure 4 and Figure 5). It has four legs not regularly set and each leg has a splitter island between entry and exit lanes; each splitter island has a pedestrian crossing with a refuge area. External diameter is 38 meters, the central island is 16.4m large with a truck apron of 1.8m and the circulatory roadway is 9 meters large. A correct alignment is not always abided partly due to the non regular configuration of pre-existing roads. A bicycle lane connects the three main urban roads.

In Table 4 requirements not met for this case study are listed. The critical points are, in fact, more since the same requirement is not met more than once as can be seen in Figure 6. In this figure the specific spot and object that does not meet some requirement is shown by a red arrow together with the requirement code.

Table 4. List of requirements that are not met for case study A

Classes of needs and environmental requirements for case study B		
Use Adequacy FR	Geometrical FR-GE	FR-GE 1.3
Safety SI	Geometrical SI-GE	SI-GE 1.1
		SI-GE 1.2
		SI-GE 1.3
	Mechanical SI-ME	SI-ME 1.2
Appearance AS	Morphological-Geometric AS-MG	AS-MG 1.3
		AS-MG 1.5
Comfort BE	Visual BE-VI	BE-VI 1.1
	Optical Luminous BE-OL	BE-OL 1.1
		BE-OL 2.1
		BE-OL 2.2
Environmental Protection SA	Ground SA-SU	SA-SU 1.1
		SA-SU 1.2
		SA-SU 1.4
	Nature and Biodiversity SA-NB	SA-NB 2.1
		SA-NB 2.2

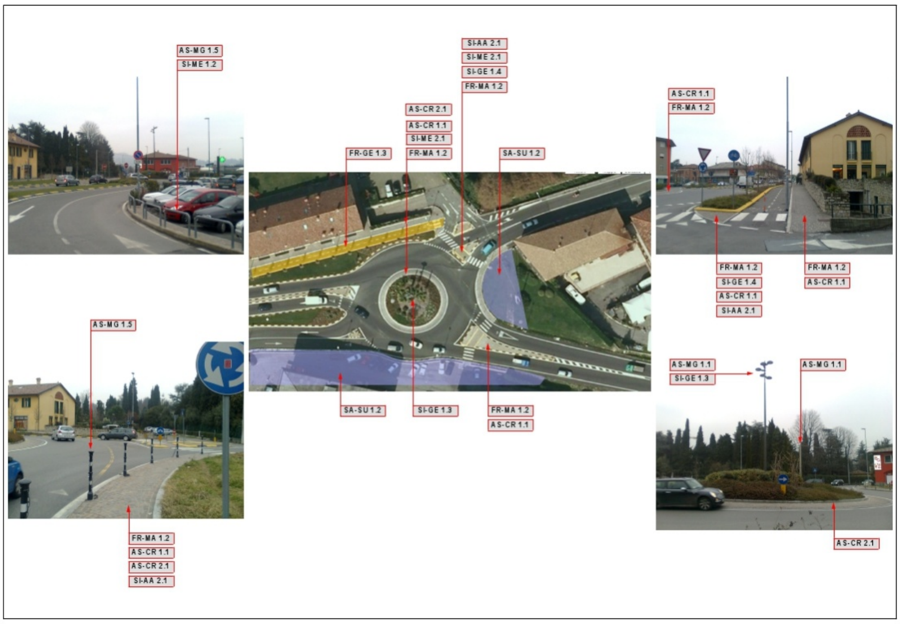

Figure 6. Map of critical points (relating to requirements that are not met) for case study A

Obviously it is possible to show all the requirements, whether they are met or not, in order to verify immediately the evaluation process.

5.2 Case Study B (Rural Environment)

This roundabout is located in a rural environment (Figure 7 and Figure 8).It has five legs almost regularly set and only two legs have a relevant splitter island between entry and exit lanes; no pedestrian crossings are present in the area. External diameter is 65 meters large, the central island is 39 meters large with a truck apron of $2m$ and the circulatory roadway is 11 meters large.

The alignment is always correct for all entries thanks to the large dimension of the roundabout. At about 120 meters northward the roundabout, the ancient Mapelli Mozzi mansion house is placed; the palace was built in the late XVIII century in the neoclassic style.

In Table 5 requirements that are not met for this case study are listed. As the previous case study the critical

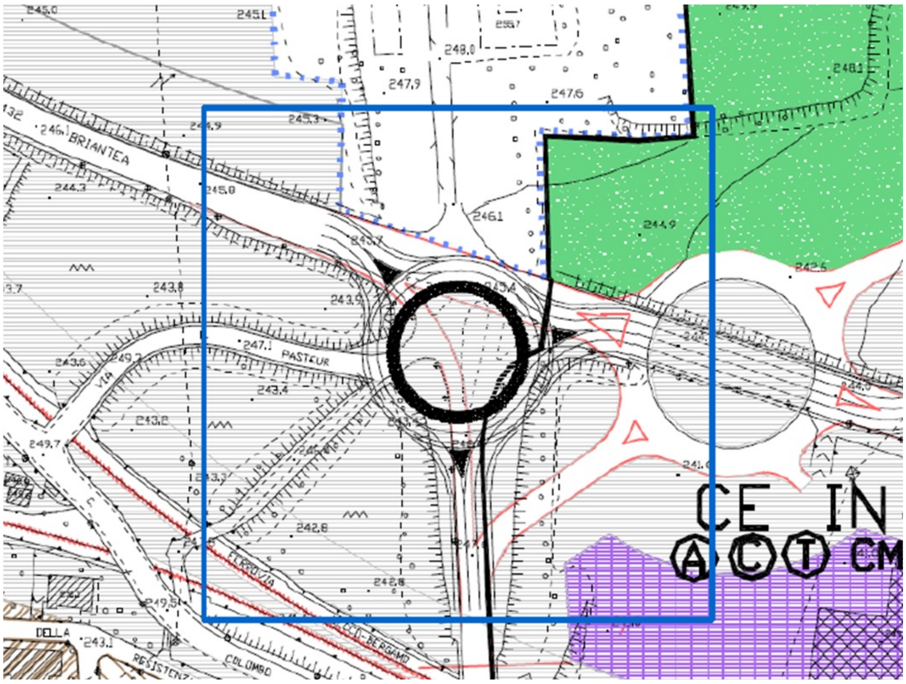

Figure 7. Layout of the roundabout of case study B (city of Ponte San Pietro)

Figure 8. Aerial view of the roundabout of case study B (city of Ponte San Pietro)

points are, in fact, more since the same requirement is not met more than once as it can be seen in Figure 9. In this figure too, the specific spot and objects that do not fulfill some requirement are shown by a red arrow together with the requirement code.

6 CONCLUSION

In general, in order to face the problem of the environmental and landscape insertion of roundabouts, they, like any other artefact, must be considered from the point of view of the definitions laid down by the European Council on landscape, ratified in Florence, Italy in

Table 5. List of requirements that are not met for case study A

Classes of needs and environmental requirements for case study B		
Use Adequacy FR	Geometrical FR-GE	FR-GE 1.3
Safety SI	Geometrical SI-GE	SI-GE 1.1
		SI-GE 1.2
	Mechanical SI-ME	SI-ME 1.2
Appearance AS	Morphological-Geometric AS-MG	AS-MG 1.3
Comfort BE	Visual BE-VI	BE-VI 1.1
	Optical Luminous BE-OL	BE-OL 1.1
		BE-OL 2.1
		BE-OL 2.2
Environmental Protection SA	Ground SA-SU	SA-SU 1.1
		SA-SU 1.2
		SA-SU 1.4
	Nature and Biodiversity SA-NB	SA-NB 2.1
		SA-NB 2.2
	Landscape SA-PA	SA-PA 1.2
		SA-PA 2.2
		SA-PA 3.2
		SA-PA 3.3
		SA-PA 3.4
		SA-PA 3.5
	Cultural Heritage SA-BC	SA-BC 2.2
		SA-BC 2.3

Figure 9. Map of critical points (related to requirements that are not met) for the case study B

2000, about the meaning of landscape, landscape policy, landscape quality, safeguard, management, planning. The present discussion of the environment makes a series of considerations that are designed to give an effective answer to the above mentioned problem: the extension of the landscape, eco-compatibility and the necessity of reducing non-renewable energy consumption, the reduced availability of natural resources, the demand for a constant verification of the quality of the landscape. The multi-disciplinary capacity necessary to face the global environmental questions (for new various situations, needs and problems) can be, unlike other approaches to specific problems (related to urban planning), easily achieved by using an integrated technological approach. The technical-scientific analysis represents a method that is capable of facing the complexity deriving from the new landscape concept.

A dynamic planning, following the evolution of land transformation, must be based on a willingness to consider as part of a single system all the problems to be faced. It requires a tool that takes into consideration quality, based on the correlation between needs, requirements and performance. The concept of needs, requirements and performance is inevitable in a method where quality is achieved independently of the materials and techniques used. The components of the triad needs-requirements-performance become the cornerstones of the method and thus the technical specifications become the quantifiable determiners of quality. An environmental planning aimed at a constant quality of the landscape, for all its many characteristics (valuable landscapes, degraded areas, anthropic or natural lands, and so on), requires an approach that is capable of conforming to a constantly changing realty, such as that defined by a needs-performance set. This approach has been applied to two case studies, examples of existing roundabouts, one located in an urban context, the other in a rural one. These examples cannot be considered comprehensive of all roundabouts since there are also other types of roundabouts in the Italian scenario, but they are certainly emblematic and useful to understand the proposed method. The real landscape and environmental insertion has been checked according to their compliance or otherwise to the requirements previously set out for the many correlations between environmental classes of needs and requirements. The final evaluation sheet allows us to carry out this task. No compensation between items is considered now; but it is obvious that the evaluation could be dealt with by a multi-criteria approach where the criteria set is simply the requirements set. Indeed, this could be a possible development of this research.

It should be understood that this method requires the survey not only of all information about all elements of the roundabout but also an in-depth knowledge of the territory where the roundabout is located in order to determine the level of fidelity to the defined requirements for the environmental insertion. This implies a level of knowledge generally greater than that necessary for the roundabout design and in this sense the method is more expensive; two considerations should be held in mind, however:

- i a roundabout is often preferred (at least in Italy) for its greater appeal in landscape insertion especially in an urban context; therefore it should fit into the landscape;
- ii the method forces us to analyze the roundabout (as well as the adjacent environment) from a different point of view (needs and requirements) in respect of norms and design rules; this requires the designer to consider accurately all possible users and their needs and to improve the quality of the design itself accordingly.

Besides this, the proposed tool, though it has been used in this research for the evaluation of a specific structure such as a roundabout, is flexible and versatile enough to be applied during the planning phase too or to be the evaluation tool for landscape and environmental insertion of other types of road structures.

REFERENCES

Abdel-Aty, M. A. and Hosny, Y. (1997). *State-of-the-art Report on Roundabouts Design, Modeling and Simulation.* Department of Civil and Environmental Engineering, University of Central Florida, Florida, United States.

Austroads (1993). *Guide to traffic Engineering Practice.* Part 6 Roundabouts, Austroads, Sidney, Australia.

Becker, R. (2008). *Fundamentals of Performance-based Building Design.* Faculty of Civil and Environmental Engineering Technion - Israel Institute of Technology, Haifa, Israel.

CERTU (1998). *Plans de déplacements urbains. Guide méthodologique.* Certu, Lion, France.

CERTU (1999). *Carrefours urbains.* Certu, Lion, France.

CETUR (1988). *Conception des Carrefours a sens Giratoire Implantes en Milieu Urbain.* Centre d'Etudes des Trans-ports Urbains, Ministère de l'Equipement, du Logement, de l'Aménagement du Territoire et des Transports.

Council of Europe (2000). *European Landscape Convention.* Florence, Italy.

Curti, V., Marescotti, L., and Mussone, L. (2008). *Rotonde: progetto e valutazione delle intersezioni a rotatoria (Roundabouts: Design and evaluations of roundabout intersections).* Maggioli, Italy (in Italian).

Daniels, S., Brijs, T., Nuyts, E., and Wets, G. (2011). "Extended prediction models for crashes at roundabouts." *Safety Science*, 49, 198–207.

FHWA (2000). *Roundabouts: An Informational Guide*. U.S. Department of Transportation, Federal Highway Administration, United States.

Ginelli, E., Mussone, L., Riva, G. D., and Trabucchi, M. (2010). *Guidelines for Level Non Signalized Intersection Design*. Maggioli, Italy (in Italian), Chapter Linee Guida per la valutazzione di impatto paesaggistico e ambientale per le rotatorie (Guidelines for landscape and environmental impact evaluation for roundabouts).

Mandavilli, S., Rys, M. J., and Russell, E. R. (2008). "Environmental impact of modern roundabouts." *International Journal of Industrial Ergonomics*, 38, 135–142.

NCHRP (2007). *Roundabouts in the United States*. Report 572, United States.

Pochowski, A. and Myers, E. J. (2010). "Review of state roundabout programs." *The 89th Annual Meeting of the Transportation Research Board*, Washington, D.C., United States.

Pompidor, J.-P. and Fain, J.-C. (2004). *La Ronde Catalane*. Les Presses Littéraires.

Queensland Government (2002). *Road Planning and Design Manual*. Department of Main Roads, Queensland, Australia.

SETRA (1997). *Documentation Technique 44. Carrefaurs Giratoires: Evolution des Caractéristiques Géométriques*. Minist'ere de l'Equipement, du logement, de l'Aménagement du Territoire et des Transports.

Szigeti, F. and Davis, G. (2005). *Performance-based Building: Conceptual Framework*. PeBBu Final Report, CIBdf, Rotterdam, The Netherland.

Taekratok, T. (2000). *Modern Roundabouts for Oregon*. Oregon Department of Transportation Research Unit, Oregon, United States.

UNI (1999). *Standard 10838: Building Terminology for Users, Performances, Quality and Building Process*.

Züst, A. (2003). *Roundabouts*.