A method for landscape and environmental impact evaluation of roundabouts

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A METHOD FOR LANDSCAPE AND ENVIRONMENTAL IMPACT EVALUATION OF ROUNDABOUTS

ABSTRACT

The interest of researchers and practitioners on roundabout solutions for level intersections has been growing increasingly in the last decades and this has stimulated new paradigms for performance evaluation. The often larger areas occupied by this type of intersection, both in a rural and in an urban environment, require special attention on the use of ground and the preservation of the natural, environmental and architectural heritage and also present the opportunity for evaluating their impact on the landscape and environment.

The paper proposes a new method for evaluation 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.

The method has been developed taking into consideration especially European (and, more specifically, Italian) experiences but results and conclusions can be considered as general.

After a synthetic glossary of the specific language and approach used, the paper provides a series of data to be collected in order to achieve the roundabout evaluation: the list of the classes of needs, requirements and performance on which evaluation is based; the basic geometrical/functional/material elements into which to break down the roundabout; the relationships between classes and basic elements. Standard sheets on which roundabout data can be collected are also prepared. Finally a complete evaluation sheet is provided.

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 (1). 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 (2; 3; 4; 5; 6; 7; 8; 9; 10; 11; 12; 13; 14).

However, the inner part of roundabouts (the central island) is often used, especially in urban environments, for the insertion of monuments, trees and advertising boards. 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 a careful reading of the guidelines proposed by the European Landscape Convention, Florence in 2000 (15). The first article of the 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 leading 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 as described in the next chapter.

The method proposed in the paper for roundabout evaluation is a synthesis of the guidelines prepared for the Italian Ministry of Universities and Research (16). 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 defining 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.

The reference theory: an approach based on the definition of needs and performance

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 (17; 18).

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 for this reason 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 the quantifiable determiners of quality.

Historically the norm was aimed at the regulation of objects; its purpose was 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 stated its own evaluation and directive character through an explicit description of objects and it made prescriptive technical and technological choices and, consequently, also defined 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 was 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" aiming (not explicitly) at 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, make 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 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 aims 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 norm which recognizes the fundamental role of the user who becomes the starting point of a design through a definition of his needs.

Basic definitions

The UNI 10838 standard (19) (the Italian ISO), issued in 1999, "Terminology for users, performances, quality and building process", explains the above mentioned concepts by means of the following definitions:

- **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);
- **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;

- **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;
- **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;
- **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.

METHOD

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. FIGURE 1 proposes a schematic representation of the information structure.

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.

After this survey 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.

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:

- the class of needs uses:
  - adequacy
  - safety
  - landscape and environmental qualifications
  - management
- The class of requirements:
  - accessibility
  - risk perception
  - landscape and environmental compatibility
  - maintainability
- The components of a "functional island" (“type”):
  - Central island
  - Circulatory roadway
  - Entry links
- The variable parameters:
  - context – category of landscape
  - categories of traffic (users, vehicles)
  - volume of traffic (for vehicles, motorcycles, cycles, pedestrians)
- The non variable parameters:
  - objects (supplementary systems, signs, technical and underground utilities)
  - regulation norms

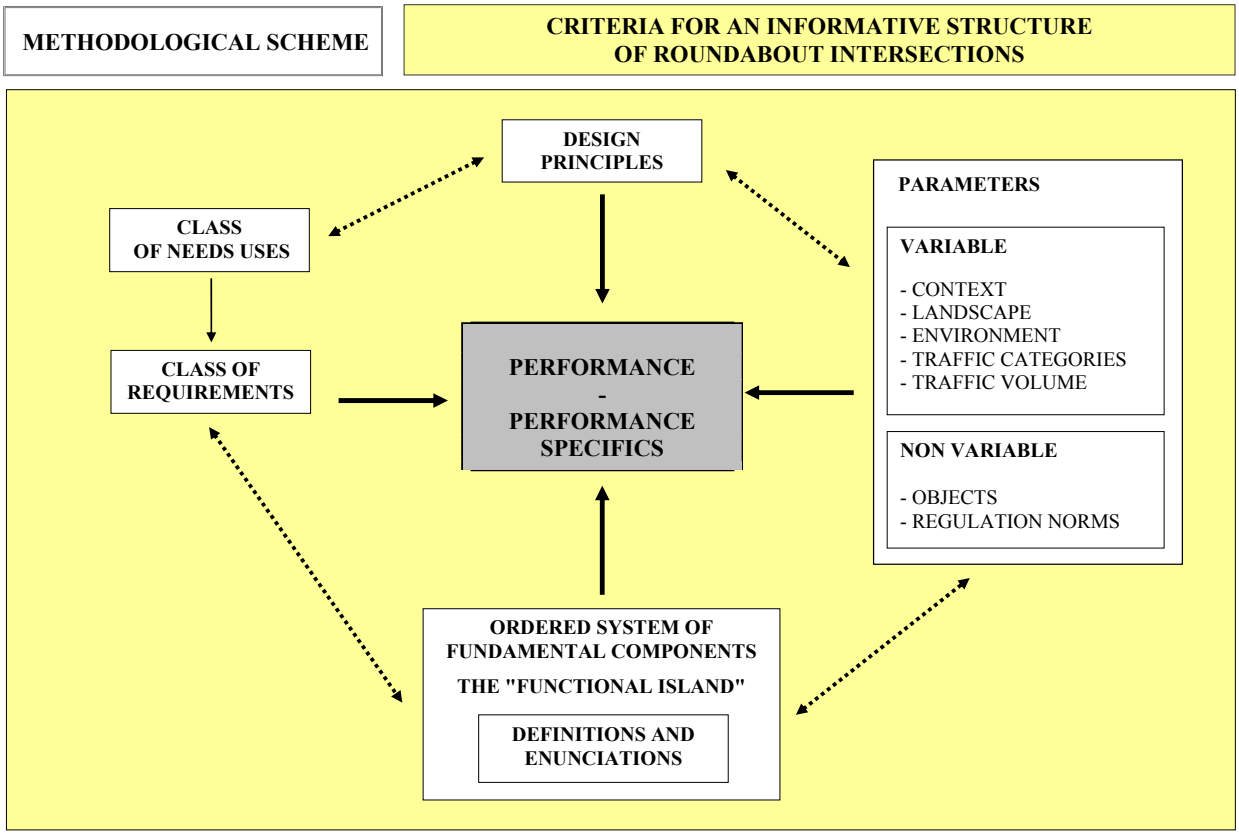


FIGURE 1 Methodological scheme: criteria for an informational structure of roundabout intersections.

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:

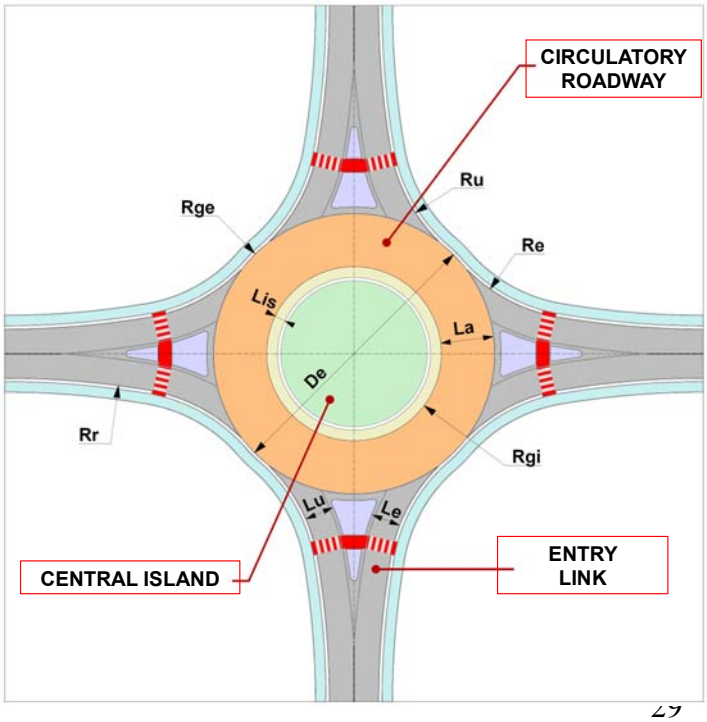
- context
- planimetric conformation
- dimensions
- layers / materials
- supplies

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 2).

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 relation 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.



Legend
De: inscribed circle diameter
Rge: exit radius
Rgi: circulatory radius
Re: entry radius
Ru: exit curb radius
Rr: flare entry radius
La: circulatory roadway width
Lis: truck apron width
Le: entry width
Lu: exit width

FIGURE 2 The basic components of a "functional island".

The scheme of a roundabout and its breakdown into geometrical/ functional/materials elements

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, exit width.

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

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

Central Island			
Morphology	**Conformation**	**Characterizing Elements**	**Size**
round	with apron	type of finish	diameter
elliptic	Raised	paved	truck apron width
"oblong" or irregular		green	
		presence of natural elements	
		presence of artificial elements	
Circulatory Roadway			
Morphology	**Alignment with respect to link axes**	**Size**	**Traffic categories**
round	central position	width	vehicles
elliptic	not aligned	inscribed circle diameter of roundabout	pedestrians
"oblong" or irregular		exit radius	animals
		circulatory radius	
		angle between consecutive legs	
Entry Links			
Constituent elements		**Size**	**Traffic categories**
lane		width	vehicles
quay		entry radius	pedestrians
splitter islands		exit radius	animals
sidewalks		flare entry radius	
bicycle path			
crosswalks			

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, A and B.

Other tables refer to:

- 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;
- variable parameters (context, classification of landscape, classes of traffic, volume of traffic) and non variable ones (supplementary systems);
- for each class of needs, the detailed list of needs; for each need the respective parameters for controlling needs, requirements and technological performance;
- the critical aspects which constitute a priority to be met through specific actions as a function of variable parameters to be taken into account;
- 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;
- 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.

TABLE 3 presents the sheet 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 are listed: localization and context, planimetric and altimetric conformation, dimensions, layers and materials, supplies.

Evaluation of impacts and the evaluation sheet

TABLE 4 fixes the performance to be guaranteed by all 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 places thanks to the numerous tables makes 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.

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

Fundamental components of a "functional island" type	Central island	
	Circulatory roadway	
	Entry links	
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 maneuver and the distance
		easy orientation
	Materials	roughness control
	Efficiency	constant performance in operation
Safety	Geometrical	safety of movement in space
	to 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 color 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	

TABLE 2B The "Functional Island" ("type"): Fundamental Components, possible classes of needs and environmental requirements (continued)

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

TABLE 3 The "Functional island" sheet: Characterization, description, geometric and matter survey

SITE:				
Context	urban			
	rural			
	planimetric form	round		
		elliptic		
		"oblong" or irregular		
	planimetric dimensions	max. diameter up to 10 m		
		max. diameter from 10 to 50m		
		max. diameter from 50 to 80m		
		max. diameter over 80 m		
	location relative to entry links	central position		
		offset position		
	altimetric conformation	planar surface	horizontal	at road level
				At level
			Inclined	like the roundabout plane
				With a different grade
		with altimetric difference	up to 1 m	
			from 1 to 1,80m	
			over 1,80 m	
	natural surface / materials	clay surface		
		grass surface		
		bark		
		pebbles, stones		
		flooring	draining	
			waterproof	
	artificial surface / materials	continuous flooring	draining	
			waterproof	
		discontinuous flooring	draining	
			waterproof	
	natural elements	flowers		
		shrubs		
		trees		
		watercourses		
	artificial elements	road signs	prescriptive	
			informative	static
				dynamic
		protection	roadside posts	
			guardrails	
			low walls	
		technological systems	poles, lighting towers	
			photovoltaic panels	
			wind poles	

TABLE 4 The Evaluation Sheet (the whole class of needs) (legend: N.A. = not applicable**)**

SITE.:

Class of needs and environmental requirements		**Performance of Fundamental components (Central island, circulatory roadway, entry links)**	**fulfillment check**		
USE ADEQUACY FR The set of conditions in which users (drivers and pedestrians) can use the "Functional Island" properly	**GEOMETRICAL** GE				
	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 "Functional Island" 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	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

	roughness of pavement surfaces) FR-MA 1	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
SAFETY SI Set of requirements for the safety of users, and prevention of damage depending on accidental factors, during work	GEOMETRICAL SI-GE				
	Safe use of road traffic spaces: of vehicles, motorcycles, bicycles, pedestrians (presence of signs, no barriers, connection of height differences, presence of vertical misalignment and changes of pavements, reduction of the longitudinal gradients of entry links to avoid glare by headlights) SI-GE 1	In order to provide safety barriers and retaining systems, preference should be given to an arrangement of safety areas with supplies and forms integrated with the surrounding landscape SI-GE 1.1	yes	no	NA
		Lighting elements, necessary to guarantee a sufficient view of the different spaces, should be designed according to the dimensions necessary for effective lighting, and with forms, materials, and colors in harmony with the surrounding landscape SI-GE 1.2	yes	no	NA
		Signs and lighting elements should not represent an obstacle to landscape perception because of their size and number SI-GE 1.3	yes	no	NA
		Altimetric changes for raising the road surface and changes in pavement type with a view to increasing safety for weak users should be made with materials that have a dialectic relation to those already present and should be in harmony with the layout and colours of the surrounding landscape. SI-GE 1.4	yes	no	NA
	TO ATMOSPHERIC AGENTS SI-AA				
	Rapid emptying and storm sewer of rain water SI-AA 1	Storm water sewers and waste water works should conform as far as possible to the need to collect and purify water by the creation of specific environmental habitats SI-AA 1.	yes	no	NA
	Frost resistance SI-AA 2	Materials used should be in dialectic relation to those present, in harmony with the outlay and colors of the surrounding landscape SI-AA 2.1	yes	no	NA
	MECHANICAL SI-ME				
	Safe use of road spaces (stability and resistance of structural elements that make and demarcate the road space; crash strength of protective structures) SI-ME 1	Intrusion or barrier effects in the landscape and in the perception of the "functional island" should be avoided when safety barriers or other retaining elements are built. Preference should be given to an open plan solution such as inserting openings onto the landscape. SI-ME 1.1	yes	no	NA
		Design prospective works intended to increase the safety of users (anti-glare barriers, windbreak barriers, safety barriers and split islands) by introducing vegetation SI-ME 1.2	yes	no	NA
		Design prospective works for protecting artifacts by planting trees and strengthening embankments by introducing vegetation SI-ME 1.3	yes	no	NA
		To avoid visual obstruction, when fences are built near the "functional island" they should be open plan and provided with vegetation consonant with the surrounding landscape. SI-ME 1.4	yes	no	NA
	Safety in road traffic spaces (limited slipperiness in use conditions) SI-ME 2	Materials used should be in dialectic relation to those present and in harmony with the layout and colors of the surrounding landscape. SI-ME 2.1	yes	no	NA

	FIRE SI-AF				
	Safety in case of fire (limited combustibility of materials and means of reducing the spread of smoke and vapors) SI-AF 1	Propose a synthesis of materials used, preferably in a limited number, consistent with each other and, as far as possible, culled from local sources in order to provide a recognizable and coherent structure. SI-AF 1.1	yes	no	NA
		Materials used should be in dialectic relation to those present, in harmony with the layout and colours of the surrounding landscape. SI-AF 1.2	yes	no	NA
	HYGIENIC SI-IG				
	Control of morphology (accessibility for easy cleaning) SI-IG 1	Forms and spaces dedicated to cleanliness should have plano-altimetric features in conformity with the existing landscape SI-IG 1.1	yes	no	NA
	Safeguard of health (non emissivity of harmful substances of the materials used in working conditions) SI-IG 2	Materials used should be in dialectic relation with those present, in harmony with the layout and colors of the surrounding landscape. SI-IG 2.1	yes	no	NA
APPEARANCE AS Set of conditions regarding the perceived use: for the reciprocal relations between the "functional island" and the landscape	MORPHOLOGICAL-GEOMETRIC AS-MG				
	Control of geometric forms of spaces and supplies AS-MG 1	Pinpoint within the perception area that is visible from the "functional island" 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 "functional island" 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
		"Functional islands" 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
	MATERIC 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
INTEGRATION IN Set of conditions related to the adaptability of the elements of the "functional island" to be functionally connected each other	Adaptability to technology integration (ease inspection of technical compartments) IN 1	Assemble technical plants into a single technical and inspection compartment using a minimum of excessive elements IN 1.1	yes	no	NA
	Ease to be equipped (aptitude to allow installation of equipments and furnishings) IN 2	The forms and spaces envisaged should have plano-altimetric features conforming to the existing landscape IN 2.1	yes	no	NA
MANAGEMENT GE Set of requirements for the easy management of the “functional island"	Maintainable and repairable (ease of repair service through a general geometric form that facilitates inspection, maintenance, repairs and re-establishment) GE 1	The forms and spaces envisaged should have plano-altimetric features conforming to the existing landscape GE 1.1	yes	no	NA
	Replaceable (aptitude to allow the replacement of technical elements with others) GE 2	The forms and spaces envisaged should have plano-altimetric features conforming to the existing landscape GE 2.1	yes	no	NA
	Reduced maintenance (aptitude to require a reduced maintenance) GE 3	Potential embankments should be constructed using naturalistic engineering solutions that have a low cost of maintenance GE 3.1	yes	no	NA
		Give preference to specific herbaceous and arboreal species amongst low cost maintenance products and systems GE 3.2	yes	no	NA

		Consider the necessity of proposing solutions and choosing inert materials and vegetation that do not require maintenance costs incompatible with the accessibility of the area (for example when the central island is not designed for public use) GE 3.3	yes	no	NA
		Consider the necessity of proposing solutions and choosing inert materials and vegetation that do not require maintenance costs incompatible with the limited practicability of split islands and areas close to the circulatory roadway GE 3.4	yes	no	NA
COMFORT BE Set of conditions relating to states of the 'functional island" as appropriate to the needs, use, integrity and health of users	ANTHROPOLOGICAL-DYNAMIC BE-AN				
	Limitation of vibrations (on cars and in the environment) due to car circulation BE-AN 1	Use materials which, as regards superficial finishes, have a dialectic relation with those present all around, in harmony with the layout and colors of the landscape BE-AN 1.	yes	no	NA
	ACOUSTIC BE-AC				
	Control of environmental noise BE-AC 1	Any soundproof barriers should, if possible, be made of shrubby vegetation BE-AC 1.1	yes	no	NA
		Pavements used for softening rolling noise should be acoustic and, in any case, use materials in dialectic relation with those present BE-AC 1.2	yes	no	NA
	Limitation to the contribution of noise BE-AC 2	Insert artificial/natural barriers where they are necessary for the reduction of acoustic pollution, in harmony with the surrounding naturalistic/anthropic elements BE-AC 2.1	yes	no	NA
	OPTICAL LUMINOUS BE-OL				
	Limitation to the contribution of light pollution BE-OL 1	Soften the impact of light pollution (glare) by proposing plans that use lights integrated with naturalistic engineering technical solutions and with elements of street furniture opting for limited dimensions that do not affect the visual plane or the optical cones BE-OL 1.1	yes	no	NA
	Control of day and night-time light (no glare condition) BE-OL 2	Lighting signs and nighttime lighting control should be introduced using lights and their supporting poles that in number, size, colors and light intensity do not modify the perception of the “functional island”, of the surrounding areas or of the sky BE-OL 2.1	yes	no	NA
		With the aim of improving user visibility and safety, particularly by highlighting sensitive spots (pedestrian and cyclist crossings), lighting systems should be functionally adapted to the needs of the visual quality of the environment in question and of the existing elements of landscape and environmental value BE-OL 2.2	yes	no	NA
		Any anti-glare barriers should be made of arboreal, shrubby and herbaceous vegetation BE-OL 2.3	yes	no	NA
	VISUAL BE-VI				
	No visual obstructions along the route BE-VI 1	Lighting signs, in size and number, should not limit the visual field by obstructing perception of the environment BE-VI 1.1	yes	no	NA

	AIR BE-AE				
	Limitation to air pollution BE-AE 1	Reduction of atmospheric pollution should be carried out using sturdy vegetation, as an active element for the absorption of pollutants BE-AE 1.1	yes	no	NA
ENVIRONMENTAL PROTECTION SA Set of conditions for the maintenance and improvement of the states of overlying systems of which the 'functional island" is part	GROUND SA-SU				
	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 "functional island" the surrounding fields which would, otherwise, be cut off by the construction of the "functional island" 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 SA-AR 1	Give preference to the use of materials and components with a reduced quantity of equivalent CO_2 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
	Reduction of existing air pollution SA-AR 2	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
	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 qualitatively and quantitatively of existing natural areas and their biodiversity SA-NB 1	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
		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 "functional island" 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 SA-PA 1	Design the altimetric and planimetric geometry respecting the transformations consolidated by the surrounding landscape and existing morphologies SA-PA 1.1	yes	no	NA
		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 "functional island" 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, molded 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 artifacts; 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 artifacts 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
EFFICIENT USE OF	GROUND UR-SU				

RESOURCES UR Set of conditions to use resources of the environment in a consistent manner towards the users of the "functional island" and the environment itself in a defined economic-environment system	Limitation to ground use/waste (restriction of interventions to the minimum size required) UR-SU 1	The making of artifacts, tools and urban furniture must not entail, in their size and form, a transformation of a stabilized landscape or environment UR-SU 1.1	yes	no	NA
	WATER UR-AC				
	Reduction of water consumption UR-AC 1	Reduce water consumption for irrigation by using recovery strategies or strategies of optimal use UR-AC 1.1	yes	no	NA
		The recovery or reuse of storm-waters for irrigation should be made using artifacts that for number, size and color do not modify the perception of the spaces of the "functional island" and surrounding areas UR-AC 1.2	yes	no	NA
	ENERGY UR-EN				
	Reduction of energy consumption UR-EN 1	Lighting signs (informative, mandatory or for advertising), if envisaged, should be limited in number and of such a size that they do not obstruct the perception of a surrounding well-established territorial and natural environment UR-EN 1.1	yes	no	NA
		Supplies for the production of energy by using renewable sources and lights should be integrated with other artifacts, i.e. possible safety barriers, retaining elements or urban furniture UR-EN 1.2	yes	no	NA
	Improvement of local microclimate UR-EN 2	Use mitigation climatic systems by means of vegetal elements, introducing arboreal, shrubby and herbaceous flora preferably of an indigenous or compatible species UR-EN 2.1	yes	no	NA
	MATERIALS UR-MA				
	Use eco-compatible materials (from renewable, recycled / recovered sources UR-MA 1	Give preference to the use of materials that can be dismantled, from renewable, recycled or recovered sources that are in dialectic relation to those existing in the surroundings and in harmony with the layout and colors of the landscape UR-MA 1.1	yes	no	NA

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Requirement Code	Final remarks to integrate the performance evaluation
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CONCLUSIONS

This research has developed a new approach to the landscape and to the environmental evaluation of roundabouts and addresses an increasing need for roundabout design and evaluation. It is based on the needs and performance approach originally developed for the evaluation of building processes.

The approach is therefore the result of a complex adaptation of building processes to this specific case study and it has produced a series of tables and sheets necessary for describing the roundabout from different points of view as regards traffic operation and the needs of users.

Roundabouts are called "Functional Islands" since it is necessary to describe them from a functional point of view which is made up of three fundamental components, the central island, the circulatory roadway and the entry links, in order to make the definition and survey of all parameters easier.

Finally an evaluation sheet has been proposed in which all possible enquiries are addressed with notes to make for easier understanding.

The research concentrated on two roundabouts that can be considered representative of the evaluation problem. In fact the integration of the landscape and environmental concerns has been tackled on the basis of the fulfillment of requirements for all defined correlations between classes of needs and environmental requirements. The final evaluation sheet, allows analysts to verify the results.

A problem not yet faced in the research consists of a possible compensation between the various items. For the moment compensation has not been taken into account and therefore a negative answer to only one item implies a negative evaluation. Theoretically there are no limitations to introducing specific weights to each item and to allow for compensation using an algebraic sum of weights but this represents a very complex task which will be the object of future research.

Another problem to be faced in future research is the possible reduction of the amount of information to be surveyed and processed.

The method and the numerous sheets prepared to facilitate data survey and the evaluation itself, though designed for a roundabout can easily be extended and modified in order to:

- be applied during design;
- support a census of existing roundabouts in a certain area;
- be generalized for application to other road infrastructures and objects.

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