# *POSSIBLE DEVELOPMENT OF AUTONOMIC PROPERTIES ON MODERN ROUNDABOUTS*

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## Abstract

Development of road intersections in recent years has led to the creation of configurations that reduce the problems in terms of traffic safety, capacity, driver comfort and environment. This development is in connection with a creation of SMART CITIES and with an increasing use of technologies (e.g. wireless or conductive cables) within the various geometrical schemes; especially if areas are equipped with curbs or central islands and without of road signs.
This evolution can be defined from "autonomic" standpoint, according to functional first definition of IBM [1,2 ]. The unconventional geometries are often the presence of curbs and lane separation as the conventional ones of a central island and areas surmountable; they offer a good side of ITS systems within them.
Intelligent Transport Systems (ITS) are useful for application traffic management and as a result of their control produces huge volumes of data that are useful to support traffic operators in their decision-making linked to increasing amount of information overload.
This choice would lead to a kind of “autonomic management“ because it is assumed that such instruments can be targeted to self-repairing in case of failure, and preserving pedestrians and drivers safety.It also must be supported by good management policy related to economical aspect of road network (costs vs. gains from narrowed carriageways, less infrastructure investment, better road safety and environment...).

## 1. **The Development of geometrical layout of road intersection**

"Road intersection" is defined as the area obtained by the convergence in the same point of three or more road branches. The intersections, wherever they are localized, constitute a critical point for a road network because of the crossing of different traffic flows. They are divided into three main categories.

- Planar Intersection, subdivided in linear intersections and roundabouts,
- Traffic Light Controlled Intersections
- Not Planar Intersections

The typology of intersection has to be chosen according to specific and regulated choice criteria. Particular, the pollutants' impacts on the surrounding environment should be considered in the design phase. Most of the environmental impact of intersections is likely from energy wasted in stopping and then starting again. A controlled intersection, whether with signs or traffic signals, inevitably induces some unnecessary stopping. Interchanges (and roundabouts) less so because one may drive through without stopping when clear.

Today, after many years of experience regarding intersections, there are still different ideas about the "ideal intersection". The development of design rules and advice from an extensive body of research should allow civil and traffic engineers to produce the most effective forms of different intersection types[3].

Some of them are:

- already in frequent use (T and + intersection, hamburger, dumb-bell …);
- recent and have only been implemented in certain countries ("all ways stop", mini-roundabout, with an acceleration lane for left turners, turbo roundabout, dog-bone roundabout, compact semi-two-lane roundabout);
- still in development phases - are "still coming" (traffic-lighted two level intersection, turbo-square, flower, target, with segregated left-turn slip lanes…).

The main reasons for their implementation are the particular disadvantages of "standard" solutions regarding actual specific circumstances. Usually, these disadvantages are highlighted by low-levels of traffic safety or capacities. Roads began as a means of linking locations of interest: towns, forts and geographic features such as river fords. Where roads met outside of an existing settlement, these junctions often led to a new settlement. As road networks increased in density and traffic flows followed suit, managing the flow of traffic across the junction became of increasing importance, to minimize delays and improve safety. The first innovation was to add traffic control devices, such as stop signs and traffic signals that regulated traffic flow. Next came lane controls that limited what each lane of traffic was allowed to do while crossing. Turns across oncoming traffic might be prohibited, or allowed only when oncoming and crossing traffic was stopped. This was followed by specialized junction designs that incorporated information about traffic volumes, speeds, driver intent and many other factors. Intersections and interchanges are among the most important elements of highway networks because of their impact on both the safety and mobility of road system. Generally, intersection design includes:

- Human Factors, such as driver and pedestrian habits, reaction time, and driver expectancy;
- Traffic, including the volumes, speeds, sizes, and characteristics of the vehicles that will use them;
- Physical Elements, to account for the topography and development in the vicinity of the intersection or interchange, the angle of intersection between the roadways...;
- Economic Factors, including the cost of construction, the effect on adjacent residential and commercial properties, and energy consumption; and
- Functional Intersection Area (the area on which things "go on"),
- Environment Factor, their influence on surrounding [4,5].

Most design sources also agree that intersection designs should manage conflicting manoeuvres to facilitate safe and efficient crossings and changes in direction intersection while reducing the potential for crashes as well as their severity. This can be accomplished by:

- minimizing the number of conflict points;
- simplifying conflict areas;
- limiting the frequency of conflicts;
- limiting the severity of conflicts

## 2. Traffic safety, economic and environmental criteria for comparing conventional with unconventional intersections

Intersections and interchanges are categorized in several different ways. Some of the most common intersections are based on the grade and division of movements (at-grade, gradeseparated without ramps, and interchanges), the functional classification of the intersecting roadways (arterial-arterial, arterial-collector/local, local-local, etc.), and based on the amount of development within the intersection vicinity (central business district, urban, suburban, rural, neighbourhood, etc.). These various categories often overlap in different combinations. As a result, the design features of one set of intersections may not necessarily be the best for another. And the same story is also with interchanges; even they are up-grade. Intersections and interchanges are among the most important elements of road networks because of their impact on both the safety and mobility of road system. Intersections and interchanges are often the controlling factor in determining the capacity of urban roadway corridors. Thus, it is necessary to design both that present as few impediments to efficient travel as possible. However, intersections and interchanges are also areas of concentrated conflicting crossing, merging, and diverging traffic streams that can impact travel delay and the number and severity of roadway crashes. As a result, the goal of design is to achieve a balance between safety and mobility. Like most highway features safe and efficient traffic flow cannot be achieved by design alone. It requires a coordinated effort between, design, traffic control, traffic and land use planning as well as driver education and traffic enforcement[3].The environmental impact of roads include the local effects of highways such as on noise, water pollution, habitat destruction/disturbance and local air quality; and the wider effects which may include climate change from vehicle emissions. The design, construction and management of roads, intersections, interchanges and other related facilities as well as the design and regulation of vehicles can change the impacts to varying degrees. Nowadays the control of vehicles traffic flow in an urban environment is most important because it is related to the framework of the development of infrastructures in new residential and/or industrial zone of a growing city. If one wants to control the environmental impact of the new constructions, many physical polluting agents should be taken into account, such as noise, electromagnetic fields, fine dust and other air components, temperature and humidity Air pollution from fossil (and some bio-fuel) powered vehicles can occur wherever vehicles are used and are of particular concern in congested city street conditions and other low speed circumstances. Emissions include particulate emissions from diesel engines, NOx, volatile organic compounds, Carbon monoxide and various other hazardous air pollutants including benzene. Carbon dioxide is non-toxic to humans but is a major greenhouse gas and motor vehicle emissions are an important contributor to the growth of CO2 concentrations in the atmosphere and therefore to global warming. In general, the presence of an intersections and interchanges leads to a growth of the all pollution level in that point, proportional to the traffic flow, since there will always be many conflicting actions, such as turning, breaking, acceleration, etc. In literature, several studies tried to give estimation, both on an experimental and on a theoretical basis, of the noise and other pollutant impact of different typologies of intersections. The road pollutant emissions, above all in urban context, are correlated to many infrastructural parameters and to traffic intensity and typology. The research work on road junction geometry, carried out in European research centres, has recently allowed designing new road intersection types which are of undoubted interest, especially in terms of traffic functionality and safety, like the turbo roundabouts and other unconventional types of roundabouts[6,7].A model for the estimation the performances and the pollutant emissions into standard and turbo roundabouts were presented by Corriere at al. [8]and Guerrieri at al.[9]. A comparative analysis between conventional roundabout, turbo and flower roundabout has been carried out in terms of CO, CO2, CH4, NO, PM2,5 and PM10 vehicular emissions, evaluated by mean of COPERT Software[10] which is developed as a European tool for the calculation of emissions from the road transport sector.The model takes into account many traffic and vehicular parameters as: vehicle types, categories and population, annual mileage (km/year), mean fleet mileage (km), etc. The methodology allows calculating the exhaust emissions of carbon monoxide (CO), nitrogen oxides ($NO_X$), non-methane volatile organic compounds (NMVOC), methane (CH4), particulate matter (PM), and carbon dioxide (CO2). With the aim to identify the benefits of innovative roundabouts respect to conventional intersections in terms of road pollution emission, specific traffic analyses has been carried out. Tollazzi et al. [11]describe a criterion based on functional, environmental and economic aspects for comparing conventional roundabouts with innovative one- or two-level roundabouts. They compared different roundabout intersections: target, four-flyover, flower and conventional roundabouts. They examined eight different geometric layouts altogether: 2 layouts on two-levels (target and four-flyover roundabouts) and 6 at grade roundabouts. Comparing these schemes (Figure 1), it is possible to define target roundabout as a unconventional roundabout with lower delay and environmental costs. Thus, if we look at total costs, they are not very suited for medium-low traffic lows. Target roundabouts are very advantageous with medium-high entry traffic volumes (Qmax = 2800–3000 veh/h). Their economic advantage is increasingly significant in annual peak flows higher than Qmax = 3300 veh/h. With the objective to identify the benefits of "turbo" and "flower" roundabouts respect to conventional intersections in terms of road pollution emission, many traffic simulations have been carried out on five different geometrics layouts.The research shows that in lower traffic conditions there aren’t environmental benefits with the use of innovative roundabouts, but when the traffic intensity is high (up to 450000 veh/year). Turbo and flower roundabouts, generally, have an intermediate performance between conventional roundabouts with (1+1) or (1+2) geometry and double lane roundabouts. Also, when the right-turn percentage is higher to 70% of the total, flower roundabouts can give delays and pollutant emissions lower to those observed in the other configurations examined.

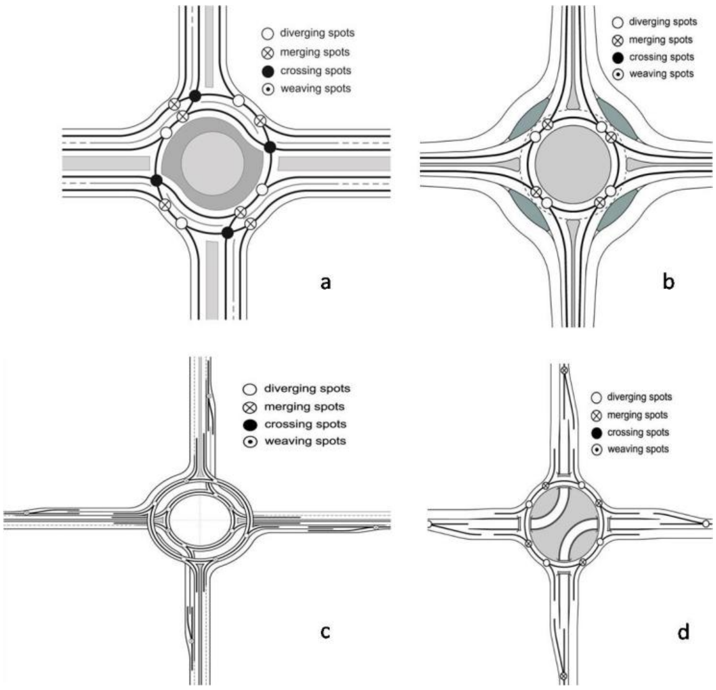


**Figure.1 comparison of black spots on unconventional schemes like: a) turbo roundabout b) flower-roundabout c) target roundabout and d) four flyover roundabout**

Four flyover roundabout is also already compared with seven other roundabout types, differing in geometric layout, number of lanes and traffic flow regulation from each other, with regard to vehicle delays and CO2, NOx, PM2.5 and PM10 pollutant emissions [11]This is also the reason why two different scenarios were considered and compared the former with Cd = 20 €/h (Figure 2a) and the latter with Cd = 30 €/h (Figure 2b)

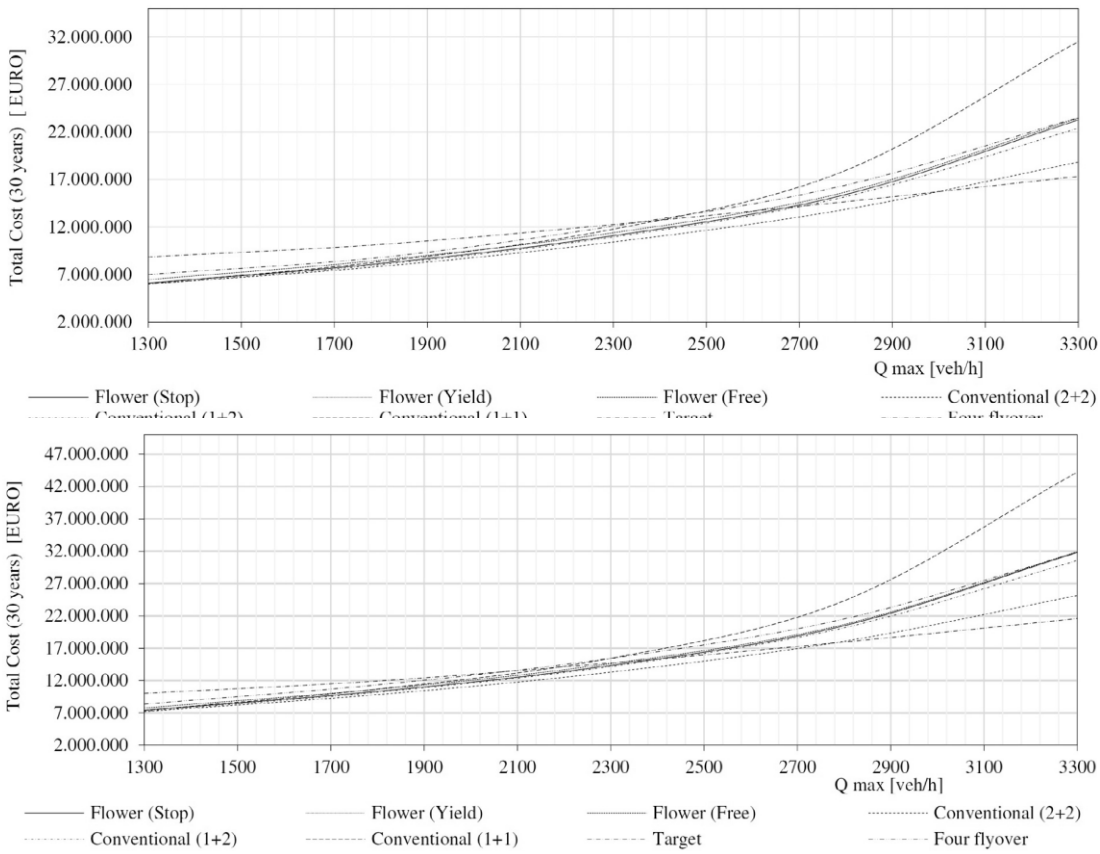


**Figure.2 comparison of unconventional schemes in terms of total costs with a) life time= 20 years and b)life time=30 years**

In general, scientific literature and law regulation consider road traffic as one of the main noise source in an urban area, together with railways, industrial areas and airports. It is quite evident that noise coming from vehicular traffic is strongly influenced by some "implicit" parameters (coming from the noise production and propagation processes), such as traffic volume, traffic flow, velocity, road features, etc., and other "specific" parameters (dependent on the particular area of interest), such as kind of vehicles, speed limits, vehicles maintenance duties, law emission thresholds, driving skills, amount and typologies of road intersections, etc. Acoustical noise produced by vehicular traffic depends on many parameters, including the geometry and the general features of the road. The presence of a conflicting point, i.e. an intersection, strongly affects and modifies the simulation strategy of noise in urban environments that is usually performed with statistical models tuned on experimental data related to standard condition (free flow traffic, intermediate vehicular volumes, etc.).All the previously mentioned studies show the comparison between different types of road intersections in order to define the most suitable geometry related to the surrounding area in terms of safety and pollutant emissions. From these assumptions, the present work is the first step to analyse the problems of vehicles (especially without user/driverless car) and the problems in terms of man-machine-environment interface through the creation of a data exchange system.

## 3. The development of autonomic properties on roundabout intersection

The concept of intelligent city has been introduced in this context as a strategic device to contain the urban modern inputs in a common framework and to emphasize the growing importance of communications technology (ICT) and information, defining the profile of competitiveness of cities, moving towards sustainability and ecological measures to both control and energy saving, optimizing solutions for mobility and safety. The importance of the two structures (share capital and environmental aspect) highlights the need for a long way to go in order to distinguish the smart city from those with greater load technology. This idea draws a clear line between the various cities, leading to the definition of smart cities and digital cities. While the technological development leads to an implementation of sensors within the various systems, on the other hand are spreading the theories on the concept of autonomic system. The autonomic approach is a tendency to cope the dynamical behaviour of growing scale of computer systems, the increase of the complexity of the system management, exploitation and the choice of the operating systems parameters according to IMB definition[1,2].This paper therefore will assume an implementation of sensors on roundabout intersections, considering like first step the selection of schemes with increase safety and environmental aspect(decrease of cost) like unconventional roundabout .The sensors will be chosen considering the development of driverless cars: for example Google Car will come with a set of sensors - cameras, laser, GPS, radar - which allows the internal processor to recognize and avoid obstacles and handle unexpected situations. In fact the car is an automatic Google does not decide what to do from time to time - a process would be too expensive in terms of computation and energy - is based rather on a set of three-dimensional maps ultra - accurate (nothing to do with those of Google Maps), which effectively recreate a virtual environment defined in great detail (the lane width, the height of the curbs) in which the car is studying how to move. The work focuses on the comparison of the conventional and unconventional patterns with particular reference to those of the latest generation (today still theoretical geometry).This hypothesis also considers the implementation of an autonomic system of sensors (e.g. type cable or wireless) that will allow for maximum driving safety. The curbs are elements that define the roadway and pedestrian walkways. They play an important role in road safety. The most innovative curbs are made with bush-hammered (with roughness) surface, more resistant and clean on the surface,able to withstand even the heavy truck, for example. Likewise spaces belonging to the circulatory carriageway and central island are a good accommodation for other type of sensors: one can imagine how the elements of the system components are bulkier inserted in the central part of the island while the cables can pass under the curbs or the surmountable island near the open space on central island. The use of the curbs at roundabouts allows the physical separation of the different lanes improving its visual impact by the driver and thus facilitating the choice of the manoeuvre. These elements, like also central island, can have a good accommodation for sensors relating to ITS systems. This paper presents the possibility of implementing wireless sensor below curbs such that they can be interfaced with the vehicle not only common but also with the latest driverless systems.

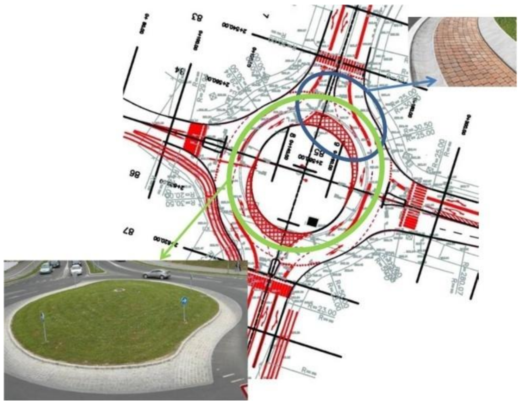

**Figure 3 ITS Implementation on curbs and central islands**

The hypothesis of implementation of sensors in the curbs and in the circulatory carriageway (or central island) therefore allows:

- Traffic lane close to the curb for electric/hybrid vehicles (mostly buses) powered by an electrical supply provided from a power source via conductive cables or magnetic inductive fields,

- Continuous data processing and output  between driver and road network,
- Proneness to create self-repairing and self-managing  systems,
- No traffic signals, traffic signs, signposts and road painting.

The development of autonomic computing systems needs to be applied quantitative formal models, describing their behaviour and dynamical management. Generally multi-level system theory has its formal potential in modelling and management of independent operating subsystems. Particularly, the coordination strategies achieve optimal control and system management. The development environmental database (and even social impacts) and impacts assessment of transportation policies are future trends. In order to fulfilling a sustainable transportation policy goals, automatic integrated simulation tools must be developed to assess the environmental impacts (or even social impacts) of traffic. Hot, cold and evaporative emissions must be studied, considering a dynamic environment (e.g. considering the variability of air temperature). Different atmospheric gases (e.g. PM, $NO_X$, CO, HC) must be analysed, not only at emissions level but also considering the effects of land use and meteorology. These new integrated system should considerer different spatial and temporal levels of application. At local and urban level, particular focus must be done in the automatic integration of detailed data (e.g. from GPS or road infrastructures) considering the definition of standard communication protocols. According Coelhoet al. [12] these new high potential models should integrate background world maps, in order to help users. Below an example of integration platforms using different model types, including pre-selection of geometry parameters of network:

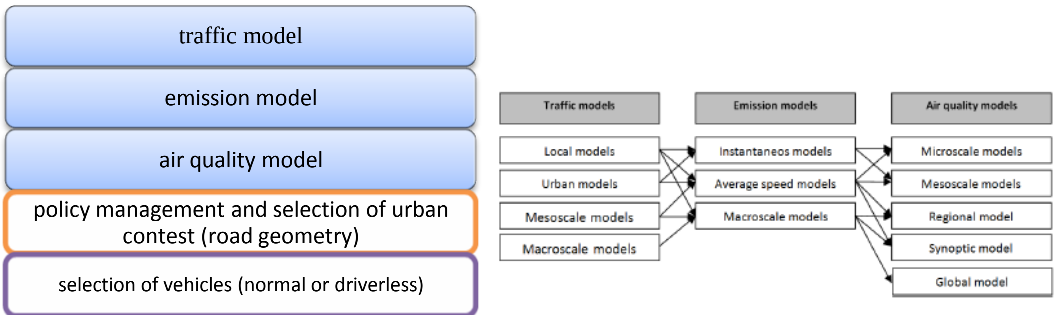


**Figure 4 integration of Coelho's graph about potential model**

At the same time this activity aims to provide a critical appreciation of the traditional and emergent thinking currently prominent in the explanation of individuals travel, including:

- economic theories of behaviour- derived demand, utility and  time value,
- transport and society  system including the "new mobility paradigm"
- flows and communicative practices
- social psychological models of attitude and behaviour.

## *Conclusion*

This paper shows the evolution of geometrical schemes of intersection, analysing comparison in terms of geometrical, environmental and safety aspect.The evolution of roundabout, especially unconventional type, during next decades will be implemented with ITS system: The sensor implementation offers opportunity to define autonomic properties of road/sensor system: it is possible to consider different sensors application of curbs or central islands to define an autonomic system able to enquire, process and layout data. However, this paper propose to focus on idea that  will be dealing with autonomous vehicles only, but design the framework so as to facilitate gradual transition towards full automation, taking into account various levels of penetration of autonomous vehicles. While it is widely accepted that fully autonomous vehicles have the potential to improve safety and efficiency, further top studies are needed to investigate the level of penetration required to realise these benefits and how vehicles of varying levels of automation can collaborate, both amongst themselves and with city infrastructures, and this is one of the aspects our proposal can address. The idea would be for each (smart) city to support autonomous navigation. Whenever a car enters a city it is automatically registered within the system along with public information automatically provided by the car (such as destiny, source location, current position and other indicators such as fuel, speed, etc.). The system would then receive information to route it through the best path in accordance with different metrics (such as avoiding traffic jams, areas with many emissions, personal safety and such). When a car leaves the city it is not considered within the system anymore. The system should consider all the details of the traffic management both at microscopic and macroscopic level. At the tactical level the paper considers how autonomous vehicles exchange information among theme g.a car accident in the surroundings might be faster to notify locally than globally. At the higher (strategic) level we should consider how a single infrastructure shares both private and public information among different agents. This second level makes sense to be able to address nominal scenarios (i.e. the typical traffic management of every day, distinguishing between working days, holidays and weekends) and exceptional scenarios (i.e. exogenous events such as a sport event, the visit of an international authority and such).The possibility to implement roundabout with ITS sensors can be generated proneness by local authority to select specific policy to define National Design Guidelines and to increase the building of unconventional roundabout and application of sensors on these.

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