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A GRID OF MATERIAL AND IMMATERIAL LABORATORIES FOR A SUSTAINABLE TRANSPORTATION SYSTEM: THE RE.S.E.T. PROJECT IN SICILY

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ABSTRACT

Transportation is a crucial sector, to be suitably approached in order of getting human activities in more environmentally sustainable paths. In fact, in developing, as well in less developing, countries people and freights mobility are responsible of important amount of pollutant emissions and are cause of significant levels of energy consumptions. In this paper, a Sicilian regional project is presented, aiming at establishing an interconnected grid of material and immaterial laboratories. These laboratories, that are devoted at inducing more virtuous behaviours in the transportation policies, are constituted by equipment and software tools, mainly located in the region's universities, acting as monitoring and simulation stations. After a description of the structure of the grid, first results of the laboratories activity are provided, along with an estimation of the expected improvement in the environmental and energy efficiency of the transportation sector in Sicily.

Keywords: transportation laboratory, sustainability, roundabouts, road pavement, railway track.

INTRODUCTION

The transport sector, as a whole, contributes 4.6% of Gross Domestic Product (GDP) to the EU Member States. In EU it employs around 10 million people, equal to 4.5% of total occupied population. Manufacture of transport equipment provides an additional 1.7% GDP. The 13.2% of every household's budget is spent on average for transport goods and services [1].

In the EU, transport depends on oil and oil products for more than 96% of its energy needs [2].

Transport greenhouse gas emissions, including from international aviation and maritime transport, increased by around 34% between 1990 and 2008. Over the same period, energy industries reduced their emissions by about 9%.

Transport is responsible for about a quarter of the EU's greenhouse gas emissions. 12.8% of overall emissions are generated by aviation, 13.5% by maritime transport, 0.7% by rail, 1.8% by inland navigation and 71.3% by road transport (2008) [3].

In order to prevent undesirable effects, European Commission's White Paper "Roadmap to a single European transport area" [4] identifies a series of actions to be taken to enhance transport sustainability such as:

- developing and deploying new and sustainable fuels and propulsion systems;
- optimising the performance of multimodal logistic chains, including by making greater use of more energy-efficient modes;
- increasing the transport and infrastructure efficiency with information systems;
- market-based incentives.

The main objective of these measures is, compared to 1990's emission values, the reduction of total CO_2 emissions of 60% by 2050. The CO_2 emissions from air and maritime transport should be cut by 40% and besides using low-carbon sustainable fuels in aviation to reach the 2050 target.

More recently, the "Clean Power for Transport package" (2013) [5] aims to improve some measures concerning environmentally sustainable transport, and in particular:

- charging points be installed in every UE Member State;
- liquefied natural gas (LNG) refuelling stations be installed in all 139 maritime and inland ports on the Trans European Core Network by 2020 and 2025, respectively;
- by 2020, LNG refuelling stations are installed every 400 km along the roads of the Trans European Core Network.

In recent years, international community has made many efforts to cope with accidents, particularly with road transport accidents.

Preliminary estimates of mortality rates, calculated as ratio between the number of deaths in road accidents and the resident population (rates per 1, 000, 000 inhabitants), recorded in 2013 across UE28 Member States, vary between 27 for Sweden and 93 for Romania. The value for Italy is equal to 57 deaths compared to a European average of 52 deaths per million of inhabitants [6]. In Italy, 182,700 road accidents resulting in injury were counted. The number of deaths, within thirty days, is 3, 400, while the injured persons are 259,500. Moreover, social cost of road accidents is equal to 2% of GDP [7].

With reference to Sicily, in 2011, road accidents number with injured people is 13, 283 (an average of 36

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per day); while the number of deaths is 271, and about 20,129 the injured people.

Therefore, costs for road fatalities amount to 407, 581.290 €; whereas for road accidents with people injured is up to 849,826.251 € [8].

In order to increasing its economic and social cohesion, reducing inequalities caused by infrastructures, reaching the goal of a single market, the European Economic Community established a programme so named TEN-T (Trans-European Transport Networks).

The Regulation COM (2011) 650 proposes a dual layer approach, comprising a comprehensive network and a core network [9].

The comprehensive network constitutes the basic layer of the Trans-European Transport Networks (TEN-T) and is to be in place by 2050; whereas the core network is to be in place by 2030.

They have different functions:

- the Comprehensive Network provides for connections within Member States;
- the Core Network connects all 28 EU Member States and with neighbouring countries' transport infrastructure networks and it is a prerequisite to achieve the goal of a single market.

In this context, Sicily is concerned with The Scandinavian-Mediterranean Corridor.

Figures 1 and 2 show the Comprehensive and Core Networks broken down by type; besides, in Table-1 ports and airports including both layers - Comprehensive and Core Networks. For more information, please, see Regulation (UE) no. 1315/2013 [10].

Therefore, it is evident that transportation sector is a complex system and, consequently, its approach should be holistic, and not simplistic, as in the past.

In accordance with this principle, and in order to contribute to scientific studies that focus on efficiency, sustainability and transport safety, Sicilian Universities provide for a new integrated system of laboratories created within the project RE.S.E.T. (A network of laboratories created for sustainability and effectiveness of Sicily transport network) [11] - in short RE.S.E.T laboratory.

Figure-1. Sicilian railways in the Scandinavian-Mediterranean Corridor.

Table-1. Core and comprehensive port and airport terminals in Sicily.

Terminal	Airport	Port
Augusta		Core
Catania	Comprehensive (Fontanarossa, Comiso emergency runway)	-
Gela	-	Comprehensive
Lampedusa	-	Comprehensive
Messina	-	Comprehensive
Milazzo	-	Comprehensive
Palermo	Core	Core (Palermo, Termini Imerese terminal)
Pantelleria	Comprehensive	
Siracusa	-	Comprehensive
Trapani	Comprehensive	Comprehensive

Figure-2. Sicilian road network in the Scandinavian-Mediterranean Corridor.

The RE.S.E.T. project in Sicily

RE.S.E.T. is a Sicilian laboratories network created by four Sicilian universities (Catania, Enna, Messina and Palermo) working in a partnership with others three Regional Authorities (University Association of the Province of Palermo; Local Authorities of the Province of Palermo and Local Authorities of the Province of Enna).

By 2015, thanks to the total funding of 12, 500, 000 €, the advanced technology centre shall have instruments to make it the reference point for transport industry, mobility and logistics sectors, in the whole Mediterranean basin.

Some examples of equipment:

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- A FFS (Full Flight Simulator) for a fixed-wing aircraft and a rotary wing aircraft; (University "Kore" of Enna) - estimated cost: 5.360.000, 00 €;
- Topographic Surveys Equipment (University of Messina) - estimated cost: 773.100,00 €;
- KMW Truck Driver Simulator with a 6 degrees of freedom (University of Palermo) - estimated cost: 650.000,00 €;
- ITS Laboratory (University of Catania) - estimated cost: 600.000, 00 €.

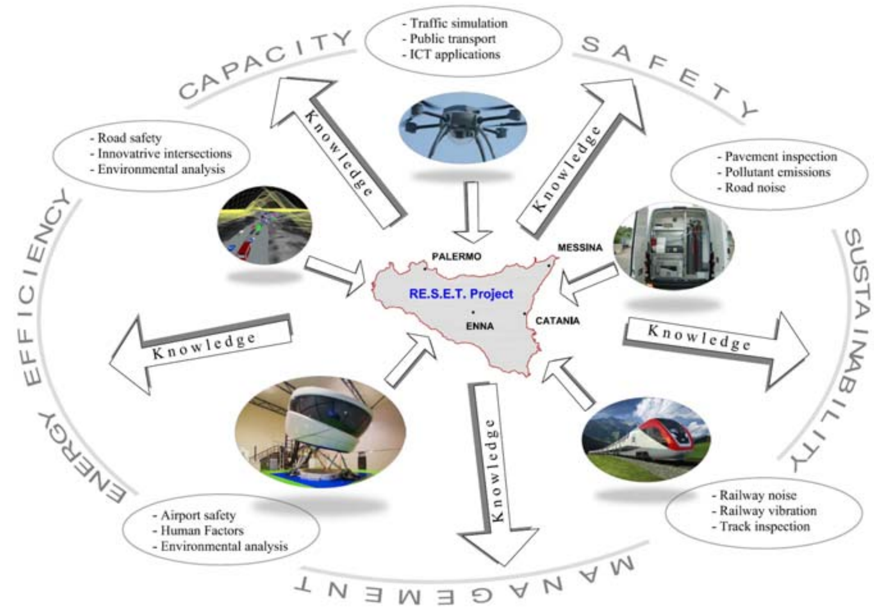

Figure-3. RE.S.E.T laboratory and major fields of study.

Additional equipments

- advanced road pavement inspection device;
- spectrometer for monitoring and detection the volcanic ash;
- instruments for electromagnetic field measurement (EMF meters);
- data logger for monitoring of artworks (bridges, viaducts, etc.);
- vibration data logger;
- a motorcycle driving simulator;
- mobile laboratory with satellite tracking to control transport and environmental parameters;
- an Unmanned Aerial Vehicle (UAV) micro drone;
- an Automatic Traffic Recorders (ATR);
- a 3D binocular-camera;
- air pollution detection laboratory;
- a mobile mapping system (MMS) for a 3d data acquisition system of road pavements;
- a ground Penetrating Radar for Road Structure

Evaluation and analysis

- a thermographic camera
- a laser profilometer to measure surface's profile;
- an infrared camera;
- carpooling software;
- two laser scanners;
- Ambulaory measurament of human motion;
- a topography and photogrammetry software;
- traffic analysis and simulation of both public and private transport by means of softwares such as Vissim, Visum, Sidra, etc.;
- a SimaPro LCA Software tool.

The laboratory network (funding by RE.S.E.T. project) has been created to carry out scientific researches for all types of transportation infrastructure (road, rail, port, airport, etc.). In addition, the RE.S.E.T laboratory should help in activities such as planning, construction and management of infrastructures already projected in Sicily [12]. In Figure-3 the diagram shows some RE.S.E.T laboratory major fields of study and modes of knowledge acquisition.

Some remarkable results

The University of Palermo (DEIM department) has already obtained remarkable results thanks to RE.S.E.T. laboratory hardware and software (i.e. high resolution cameras and software such as Vissim, Visum, Simapro e Matlab).

Studies carried out have concerned main themes such as:

- environmental features and performance evaluation criteria of innovative intersections;

- railway superstructures analysis by means of innovative techniques able to identify aggregate gradation curves of ballast, using in situ Non-destructive Inspection (NDI);
- LCA (Life Cycle Assessment) methods for the roads infrastructures, in particular for pavement (use of recycled and/or virgin materials), subgrades and guardrails.

Table-2. Main results of the researchers and involved issues.

Main results of the researches	Involved issues
A multi-criteria model for evaluating capacity, delay, pollutants at conventional and innovative roundabouts	Road safety Capacity Sustainability Energy efficiency
A novel technique for monitoring railway track. A survey on the Italian railway	Railway safety Managements
Evaluation of impacts exerted by H4 - safety barriers. A case study from real world	Sustainability Energy efficiency Managements
LCA applied to road pavement with recycled and/or virgin materials	Sustainability Energy efficiency Managements

Environmental and capacity criteria for comparing conventional and innovative roundabout layouts

In the last decades the recourse to roundabout intersections has been more and more common in urban and suburban areas, in such geometric layouts turn out to be safer [13] and provide many more benefits than conventional intersections, with or without traffic lights. Among these benefits, there is also a reduction in traffic pollutant emissions with relevant effects on the environment. Through empirical surveys has been shown that roundabouts allow obtaining a remarkable reduction in air pollutants compared to *All-Way Stop Controlled* (AWSC) as well as *Two-Way Stop Controlled* (TWSC) intersections [14].

In order to estimate the capacity and *measure of effectiveness* (MOE), closed-form models or microsimulation software packages (e.g. AIMSUN, VISSIM, etc.) can be used.

In the research, we have adopted a model developed by present authors for the capacity and MOE evaluation, while we have utilized the *Copert IV* model for the evaluation of the pollutant emissions thanks to its direct consideration of the actual running fleets. Among roundabouts, particularly remarkable are *turbo-roundabouts* [15], *flower-roundabouts* and *target-roundabouts* [16]. In turbo-roundabouts the lanes of the circulating carriageway, in entry and exit arms, are physically separated each other by kerbs. By considering this and the lane pre-selection system before entering the roundabout, capacity and levels of service can be determined through a *lane by lane* analysis. It has been shown that the capacity of each roundabout entry is influenced not only by single lane capacities, but also by the antagonist flow, the combination of the flows along circulating lanes, users' behaviour (through the psycho-technical parameters T_c, T_f and T_{min}) and by the balance of traffic flows on the arm [17]. Roundabouts with right-turn bypass lanes at all arms are characterized by the fact that right-turning vehicles do not go into the ring but benefit from an appropriate bypass lane. *Flower roundabouts* are a particular roundabout type with one circulating lane, a lane at entries and an additional lane to turn right. In flower roundabouts there are no weaving manoeuvres on the ring but there are the typical eight conflict points of a conventional roundabout with a circulating lane. Moreover, for right-turn bypass lanes there should be also considered the diversion points related to the pre-selection manoeuvre of right-turn lane and the entry points onto the flow exiting from the roundabout. These conflict points are set at a certain distance from the roundabout, where the effect on the speed moderation is less marked. Therefore, on the one hand, there is the advantage in eliminating exchange manoeuvres, on the other the disadvantage of introducing diversion and entry manoeuvres away from the roundabout. Overall, in a flower roundabout there are 16 conflict points, that is 8 conversion and 8 entry points. In the last few years a lot of research has been done to compare the capacity of turbo- and flower roundabouts with that of conventional roundabouts.

Instead, low attention has been given to "environmental performances" on air pollutant emissions which, as a matter of fact, are a discriminating factor in choosing the most suitable intersection especially in urban contexts, where appropriate policies are required to reduce pollution from the transport system [18, 19].

All above considered, through appropriate closed-form algorithms for the functional analysis (capacity and delays) of conventional and innovative (turbo and flower) roundabouts, layouts and by the help of the *Copert IV*© software, the study has indicated the emissions of some air pollutants (CO_2, NO_x, $PM_{2,5}$ and PM_{10}) in several speed [20, 21] and traffic conditions (yearly total volume and maximum hourly peak), starting from a given matrix of flow distribution.

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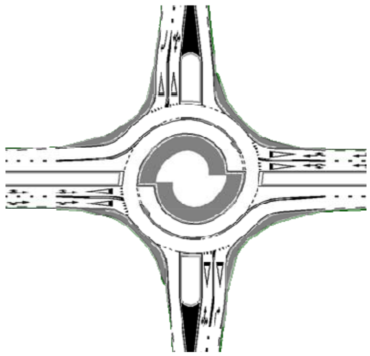

Figure-4. Typical layout of the turbo-roundabouts.

The research has thus aimed to evaluate and compare the generalised costs of seven roundabout layouts: 3 conventional (one lane at entries and one at the ring - *layout (1+1);* one lane at entries and two at the ring - *layout (1+2)*; two lanes at entries and two at the ring - *layout (2+2)*) and 4 innovative (*turbo-roundabout*, *flower-roundabout* with bypass lanes controlled by Stop, Yield or with an acceleration lane "*Free Flow slip lane*"). – and to separately examine the contributions of construction costs, costs due to vehicle delays and costs attributable to air pollutant emissions over a set time period (10 years). A suitable criterion for choosing the best geometric solution based on the annual traffic conditions and the maximum hourly peak has then been established.

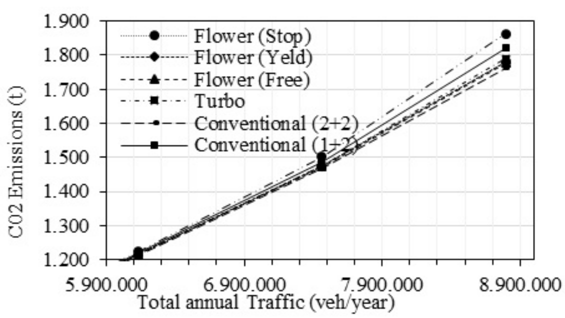

Figure-5. CO_2 Emissions.

The overall construction, management, delay and environmental costs, estimated in a 10-time period are shown in Figure-6 (each cost item has been present-valued by means of the compound interest formula, with a 1% interest rate). In order to determine such costs, the percentage distribution of vehicles with emission class Euro 2, Euro 3 and Euro 4 is supposed to remain unchanged over the period in question. This leads to a slight overestimation of environmental costs, in that over the years more polluting vehicles are progressively replaced by less polluting ones. As observed for modest flows, close to Q_{max} = 1,300 veh/h, the most cost-effective is the conventional roundabout (1+1) while the least is the free-flowing flower roundabout. As the flow increases, changes occur. Indeed, over Q_{max} = 2,300 veh/h and up to Q_{max} = 3,300 veh/h the conventional roundabout with an entry lane and a ring lane is the least cost-effective. For medium/high flows over 2,500 veh/h turbo-roundabouts have an average cost among the layouts (1+1), (1+2) and flower roundabouts. The conventional roundabouts with layout (2+2) also provide the best performances for medium/low flows, near to 1, 500 veh/h with economic benefits increasingly high when the flow increases.

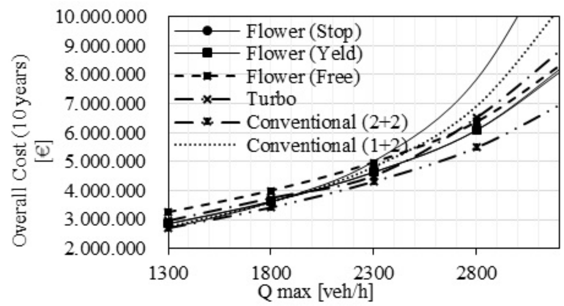

Figure-6. Conventional and innovative roundabouts overall costa as function of $Q_{max.}$

Railway ballast scanning by means of digital image processing system

The Ballast is a layer of broken stones placed and packed below and around sleepers for distributing load from the sleepers to the formation.

In a railway track, the ballast serves the following functions:

- provides a level and hard bed for the sleepers to the rest on;
- holds the sleepers in position during the passage of trains;
- transfer and distributes load from the sleepers to a large area of the formation;
- provides the necessary resistance to the track for longitudinal and lateral stability;
- provides elasticity to the track for riding comfort;
- provides effective drainage to the track.

Some of the more commonly used types of ballast are: *sand ballast*, *Moorum ballast*, *Coal ash or cinder*, *broken stone ballast*. Other types of ballast such as the *brickbat ballast*, *gravel ballast*, *kankar stone ballast* are used only in exceptional circumstances. For a good distribution of load on the formation, the minimum depth of the ballast is given by equation d = (SP-WS)/2, where SP is the sleeper spacing and WS is the width of the sleepers. The optimum thickness is usually 25 to 30 cm measured from the lower side of the sleeper but can varies depending upon the maximum speed of trains, the maximum axle loads carried and the gross annual tonnage expected. Ballast normally is comprised of particles ranging in size from 1, 18 to 63 mm, with majority of articles in the 28 to 50 mm size range. A comparison of particle sizes for British (Network Rail), German (Deutsche Bahn AG) and Indian (Indian railways systems) is given in Table-1.

Usually, to guarantee the railway safety only the rails geometry and wears are evaluated over times by means diagnostic trains equipped with laser scanner.

This device allows detecting the track geometric parameters (gauge, alignment, longitudinal level, cross level, super elevation defect, etc.) and the state of rail wear (vertical, horizontal, 45-degree, etc.) with very high accuracy, but not the ballast quality.

In fact, nowadays not any quantitative evaluation of the ballast degradations, and especially its particle size distribution, are required by international guidelines with references of the railway into operation. Nevertheless, the ability to characterize the aggregates over times with respect to size will result in better management of resources and increase the life of railway track. As a matter of fact, ballast particles can suffer degradation due to the action of traffic. The edges of the grains can become rounded and lose their interlocking effect or particles can break or crush under repeated loading [22].

Also, over time the proportion of grain distance forming an additional finer material, the filling grain that after an operating load of several million cycles encloses the skeletal grains. Thus, the internal friction angle of the material is going to be smaller, the shear strength is reduced and so the carrying capacity. In the light of the previous considerations, a specific procedure has been developed for determining railway ballast particle size distribution for railway into operation by means of the digital image processing technique (DIP) [23].

In the next future DIP Technique could be used widely for the Railway Infrastructure Monitoring (RIM) - that represents one of the most important parts of an Asset Management System (AMS) - to improve the detection of railway track irregularities.

DIP is a technique by which a scene is captured, digitized into a pixel image and then processed so that information can be extracted from the image.

The equipment used in the research comprises on high-resolution 16.1 MP camera placed on a tripod at a prefixed height (0.80 m) from ballast surface. Many field experiments have been conducted in a new railway ("*La Malfa - Cardillo*" in Sicily, Italy) because on the ballast were already available the grain-size laboratory analysis (traditional methods), carried out in compliance with the Italian Railway Network Specifications [24].

The results of the research shows that DPI are equally accurate than traditional methods and less time are required for analysis. The principal phases for DIP techniques used for the determination of the ballast aggregate gradation curve are as follows:

- Digital image segmentation;
- Threshold segmentation;
- Digital image binarization.

Figure-7. Image of ballast and Watershed transform boundaries.

Table-3. Particle size distribution of the ballast

British network rail		German Railways		Indian Railways	
Size	**Cumulative**	**Size**	**Cumulative**	**Size**	**Cumulative**
mm	**% Passing**	**mm**	**% Passing**	**mm**	**% Passing**
63	100	63	100	65	95-100
50	70-100	50	65-100	40	40-60
40	30-65	40	30-65	20	0-2
31.5	0-25	31.5	0-25		
22.4	0-3	25			
32-50	≥ 50				

By means of the procedure developed in the RE.S.E.T. Project, some geometric quantities which characterize the ballast have been carried out, as follows: *area (A); perimeter (P); compactness (C); minor axis of the ellipse; major axis of the ellipse; sphericity.*

The Figures 8 and 9 show examples of grains perimeter, roundness and aggregate gradation curves, obtained with DIP technique.

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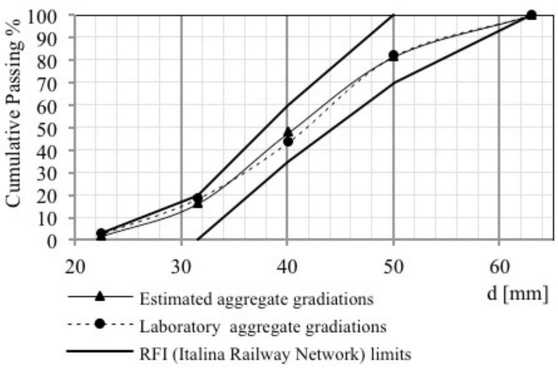

Figure-8. Aggregate gradation curves, Section n. 1 (straight).

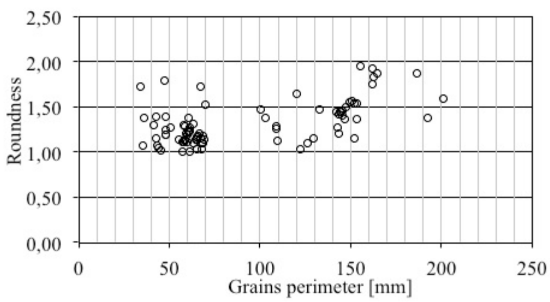

Figure-9. Perimeter and roundness of the grains, Section n. 1 (straight).

The deviation Δ between the two curves (manual measurements and DIP) is very low (Δ < 5%) for each sieve size; therefore, the proposed DIP method confirms its precision, as well as speed analysis respect to traditional methods. For this reasons, in the next future the DIP technique could be used, with a specific equipment, into the High-speed track recording cars, with the aim to allow the monitoring of railway ballast over its useful life and, therefore, for improving the railway safety [25].

Embedding "roadside equipment" into environmental assessment of transportation systems

The research is a contribution for a simple but reliable environmental assessment of roads, in their "operative" conditions. Talking of the overall environmental burden exerted by roads, when the road is equipped with all of the accessories and is therefore ready to be used, it might be regarded as determined by the concurrent burdens exerted by the road infrastructure, the traffic flow and the road components.

Starting from these considerations, in the research the environmental impact of a typical road safety component, i.e. the guardrail, is investigated. Its environmental effects are also compared with those produced by the road pavement [26] and the traffic flowing in the same road.The case study concerns the Italian Highway A20 belonging to a new two levels road intersection, which was planned near the municipality of "*Gioiosa Marea*", in Sicily.

A classical Life Cycle Assessment (LCA) methodology was applied to assess the potential environmental impacts of a highway's guardrail (H4 type) and asphalt pavement, for a period of 20 years.

The LCA method is a well-known standardized procedure that consists of four steps: goal and scope definition, life cycle inventory analysis, impact assessment, and interpretation of results [27, 28]. Data used for this LCA study were evaluated using a well-known software, i.e. SimaPro©, v. 8.01 [29].

As guardrail and pavement, the functional unit selected here is defined as 1 km of guardrail.

In this study approximately 11% of the guardrail was assumed to be replaced in 20 years. This value was determined carrying out a statistical analysis on accidents that could occur in the highway's segment analyzed. The annual crash probability has been estimated according to the Cooper study with the support of the Roadside Safety Analysis Program (RSAP) [30].

In terms of process, the global warming potential, the photochemical ozone creation potential and the eutrophication potential are mainly related to the production of primary steel. In fact 254,000 kg CO_2 eq (52%), 136 Kg C_2H_4 eq (63%), and 629 Kg $PO^{3-}{}_4$ eq (54%) comes from this process. While the process to make a semi-manufactured steel product into a finished steel product contributes significantly to the acidification potential (1,190 Kg SO_2 eq).

Results obtained from the analysis of the considered safety barrier need to be compared with the impacts exerted by the asphalt pavement and traffic flow, in order of establishing their relative contribution to the burden of the whole transportation system [31, 32, 33, 34]. In this aim the environmental impacts exerted by the components of the transportation system analyzed (i.e. pavement, traffic flow and guardrail) have been evaluated and critically compared.

To compare these components properly, the potential impacts exerted by 1 km of guardrail were multiplied by four, because 4 km is the total length of guardrail to be installed on both sides of 1 km of highway. The evaluation of traffic pollutant emissions has been carried out using the Copert IV© software.

With reference to the baseline year, the daily traffic volume AADT1, the free flow speed (that occurs when density and flow are close to zero) FFS, and the annual percent traffic growth, i, were estimated to be 13,600 veh/day, 120 km/h, and 2%, respectively.

Figure-10 shows the percentage comparison between the burdens exerted by pavement and guardrail.

This case study seems to confirm the working hypothesis, i.e. the environmental pressure of the safety barriers cannot be neglected because, as it has been demonstrated, it is often even comparable with the pavement's one.

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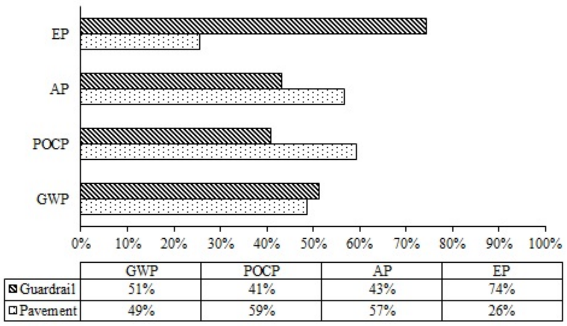

Figure-10. Percentage comparison between the burdens exerted by pavement and guardrail.

Comparative analysis of environmental impacts for different construction scenarios of a typical local road

A typical LCA frameworks of roads have focused on recycled materials for pavement layers only (reclaimed asphalt pavement - RAP), thus neglecting study of the materials used in the embankment or in the subgrade.

In the research, the LCA analysis was developed with the PaLATE software on a typical two-lane rural road (two-lane single carriageway), having a lane width of 3.50 m and paved shoulders of 1.25 m each (foreslopes rounding of 1.50 m width were also considered adjacent to the paved shoulders).

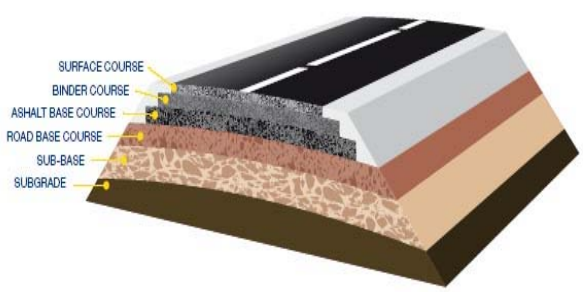

Figure-11. Road section example.

The pavement structure was of a flexible type, i.e. composed of three layers in bituminous mixtures (wearing course, binder course and base course), over a granular sub-base course, as show in Tables 4 and 5 for embankment sections and cut sections, respectively (see also the Figure-11).

Table-4. Road geometry in embankment sections.

Layer	**Thickness** (cm)
Wearing course	4
Binder course	6
Base course	10
Sub-base	35
Top layer of the embankment	35
Body of the embankment	100
Embankment foundation	35

Table-5. Road geometry in cut sections.

Layer	**Thickness** (cm)
Wearing course	4
Binder course	6
Base course	10
Sub-base	35
Subgrade	50

The analysis period considered in the research was set equal to 30 years after the initial construction.
The scenarios examined included the use of Recycled Asphalt Pavement (RAP) and stabilization with lime in situ of the existing soils.

From the combination of different amounts of virgin, recycled and improved materials a comparison study was carried out for the embankment and cut sections, on a total of 15 different scenarios. The life cycle of a road infrastructure has been subdivided into five main phases, as follow: 1) material production phase; 2) construction phase; 3) use phase; 4) maintenance and rehabilitation; 5) end-of-life phase.

Specific characteristics of materials and distances between extraction sites to the construction sites were considered for this research.

During the analysis period the maintenance of the road involves the three asphalt layers (surface, binder and base), and the sub-base 1, according to a typical maintenance activity scheduled plan.

Ten main impact categories allowing one to estimate and compare the pressures exerted by each scenario were analyzed: carbon dioxide (CO_2), nitric oxide (NOx), particulate matter (PM_{10}), carbon mono-oxide (CO), sulfur dioxide (SO_2), heavy metals (Pb and Hg), Hazardous Waste Generated (HCRA), human toxicity potential (HTP) cancer and Human toxicity potential non cancer.

The research shows that the use of lime stabilization and a higher amount of RAP gives a significant reduction in all environmental categories (i.e. CO_2 48.79%, CO 41.11%, HTPc 36.97%) [35].

Also, for the cut section when using both RAP and lime stabilization we obtain a reduction in energy consumption and CO_2 production up to the 30.35% and 30.11%, respectively.

CONCLUSIONS

In this paper, it is briefly described how RE.S.E.T.'s laboratories studies on themes such as sustainability, efficiency and transport safety, currently in progress in Sicily, has already achieved some important objectives. In particular, the University of Palermo (DEIM Department) deals with road and railway infrastructures studies, obtaining the following results:

- for each traffic situation, it is possible to identify a type of intersection in order to cut environmental costs and reduce energy consumption;
- some innovative roundabout solutions, such as turbo-roundabouts and flower-roundabouts, can increase the roundabout capacity and improve the safety;
- for each traffic situation and by means of a multiple parameters analysis, it is possible to identify, the type of intersection that permit to cut the total costs (building and maintenance costs environmental and energetic costs, vehicles delays, management costs, etc.);
- as concerns Life Cycle Assessment (LCA), it has been shown that energy consumption necessary to the guard-rail building and maintenance is not negligible compared to road pavement;
- environmental impact and comparative analysis about many construction techniques for road infrastructures has been carried out. Particularly, this shows that Reclaimed Asphalt Pavement (RAP) and lime treated soils reduce energetic costs. Over a given period of 30 years, using an elevated percentage of RAP, it is possible to obtain CO_2 emission reduction of 50% than using virgin materials;
- as regards railways track, a new non-destructive technique has been developed, using the image processing technique, to identify aggregate gradation curves. This technique should be implemented, and then used, for diagnostic trains too. In this way, it should be possible to get a better superstructure control and planning maintenance phases.

These results confirm furthermore how a holistic approach to transport studies is important.

In conclusion, RE.S.E.T. laboratories should become an important advanced technology centre to monitoring transport systems, supporting studies to improve their sustainability, in accordance with current European Union policies.

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