TRACC-EXPERT: Tool for the selection of paving techniques adapted to climate change

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ABSTRACT: From 2009 to 2012, some French, Portuguese and Spanish entities worked together under the European funded cooperation and research project TRACC – “Road Techniques Adapted to Climate Change” to select and evaluate current and new road paving techniques aiming the reduction of socio-economic and environmental impacts. The main outcome of the project is TRACC EXPERT, a guidance tool in a computer software format, which serves two purposes: (1) sequence paving techniques considering the environmental, technical, socio and economic performance, with user defined criteria weights; (2) library of materials and construction specifications, and case-studies data for all techniques. TRACC-EXPERT can be a valuable tool for spreading knowledge about existing and new paving techniques, with expectations of influencing road administration, design and construction entities in the selection of paving techniques.

1 INTRODUCTION

Worldwide, the construction industry has an important role in countries economies due to the financial values and the resources of manpower, materials and machinery involved. In the EU-27, in 2007 construction activities provided employment to 14.8 million persons and generated 9.3% of the non-financial business economy total value added (EC, 2013). Also, economic models consider that economy expansion depends largely on the availability of modern transportation infrastructures in regions/countries, either able to support local entrepreneurs and to attract investments. On the other hand, construction industry is connoted with environmental impacts of the built infrastructures and construction techniques.

The sustainable development goal, which may be defined as “ensuring a better quality of life for everyone, now and for generations to come” (UK Government), was set during the 1990’s, after the “sustainable growth protecting the environment” target, and promoted worldwide by different institutions like the European Commission and the United Nations (Pearce, 2003). More recently, in December 2008, the European Commission adopted a climate-energy package named as “20–20–20 targets” (EC, 2010), in which countries commit to achieve till 2020 the following: (i) 20% reduction in greenhouse gases emissions, compared to those of the 1990; (ii) 20% reduction in energy consumption through an increase in energetic efficiency; (iii) increase the use of renewable energy to 20% of total energy production.

Currently, the most used road paving techniques involve the use of natural aggregates from local quarries mixed in plant with hydraulic binders and/or bituminous binders at high temperatures, and the transport to the construction site. These techniques have high consumption of natural resources, non-renewable, and of energy. The acquisition of new technical skills and knowledge is fundamental so as the construction industry adapt the mode of intervention to the new context of climate change. Failing this, which means not changing current practices, it is an industry whose existence could be questioned if it does not show ability to carry out projects that consume less energy and natural resources.

TRACC-EXPERT is a software tool developed under the framework of the project “TRACC – Roads Techniques Adapted to Climate”. The project was set with the objective of understanding, analyzing, comparing and developing sustainable paving techniques employed in France, Spain and Portugal. Employed techniques are dependent on the local practices, on the availability of materials and on the contractor’s equipment/technical skills.

This paper presents firstly a summary of the project, followed by the selection and evaluation of each country paving techniques that were
considered as potentially environmentally friendly. The techniques were evaluated according to the following criteria: construction conditions, resources preservation, energy consumption, technical characteristics, social impacts and economic cost. The second part of the paper is dedicated to the presentation of TRACC-EXPERT, namely functionalities and user’s options.

2 TRACC PROJECT

“TRACC—Techniques Routières Adaptées au Changement Climatique” was a European project, funded by the Territorial Cooperation Program for the European Southwest Area (SUDOE) under goal 1: technological type development and pilot projects with high potential for transferability of results. The project was aimed at the promotion and development of road techniques adapted to climate change. It comprised an evaluation phase of the environmental friendly paving techniques employed in South Europe, the analysis of innovative techniques, a socio-economic and environmental study and the development of a support guide, which can assist decisions of road construction and management players.

The project was led by LRPC—Regional Laboratory for Pavements and Bridges, Toulouse—France, with partners from other countries of SUDOE area (France, Spain and Portugal). The other project partners are the following:

- SinesTecnopolo (Portugal)
- ATEB—Technical Association of bituminous emulsions (Spain)
- Junta de Castilla y Leon—Roads Operation and Maintenance (Spain)
- SPRIR Midi Pyrénées (France)
- CG31 – General Council - Haute-Garonne (France)

All project partners are associated with the road industry though with different activities, namely: (i) control, research and technical training laboratories; (ii) public entities responsible for road management; (iii) representatives of companies related with road construction. SinesTecnopolo assigned the development of the technical work in Portugal to the Universidade Nova de Lisboa.

The development of work was divided into the following groups of tasks:

- GT1: coordination & management
- GT2: current techniques
- GT3: innovative techniques
- GT4: socio-economic impacts
- GT5: guide to decision support

The project was developed from 2009 to 2012.

3 TRACC TYPE TECHNIQUES

The project initiated with the selection of techniques that could be considered “environmentally sustainable” or “friendly”, either often implemented (GT2) or innovative (GT3) (occasionally tested in field trials or specific road sections). All techniques were analyzed and compared with each other from the project proposed challenges standpoint, which was the inclusion in road network management of climate change and sustainable development principles.

Table 1 lists the most promising techniques often used in each country while Table 2 indicates innovative techniques that have been used in several case-studies during the past decade though there is not substantial experience about it.

### Table 1. Paving techniques selected in GT2.

<table>
<thead>
<tr>
<th>Country</th>
<th>Paving technique</th>
</tr>
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</table>
| France  | – Grave-emulsion  
– In-situ cold recycling with bitumen emulsion  
– In-situ cold recycling with cement  
– Surface dressings  
– Slurry seals  
– Hot-mix recycling (100% RAP) |
| Spain   | – Grave-emulsion  
– In-situ cold recycling with bitumen emulsion  
– In-situ cold recycling with cement  
– Surface dressings  
– Slurry seals  
– Hot-mix recycling (100% RAP)  
– Open–graded asphalt mixtures |
| Portugal| – In-situ cold recycling with bitumen emulsion  
– In-situ cold recycling with cement  
– Hot-mix recycling (low RAP content)  
– Gap–graded asphalt rubber mix  
– Open–graded asphalt rubber mix |

### Table 2. Paving techniques selected in GT3-1.

<table>
<thead>
<tr>
<th>Country</th>
<th>Paving technique</th>
</tr>
</thead>
</table>
| France  | – Grave-emulsion with 100% RAP  
– Cold asphalt mixtures  
– In-situ cold recycling with emulsion-cement combination |
| Spain   | – Cold recycling in plant with 100% RAP  
– Warm mix asphalt  
– Hot-mix recycling (up to 50% RAP)  
– Half-warm open–graded asphalt mix  
– Asphalt rubber mixtures |
| Portugal| – Warm mix asphalt  
– Half-warm recycling in plant  
– In-situ cold recycling with foamed bitumen  
– Hot-mix recycling (high RAP content) |
Table 3 shows the innovative techniques that have been tested in the 2009–2010 period.

From the comparison of the techniques listed in previous tables, it can be concluded that most techniques considered “environmentally sustainable” are common to the construction industry of the three countries. It is worthy the experience with asphalt rubber mixtures in Portugal, which incorporates a residue from end-of-life tires, and in Spain and France with grave-emulsion type mixtures, which are in-plant cold mixed, and with in-plant hot-recycling with high content of reclaimed asphalt pavement (RAP). During the last decade there were some case-studies with low temperature mix asphalts (warm and half-warm) in Iberia, and with cold mix asphalts in France.

With the objective of getting more information about some new techniques, which were identified as promising, four field trials were carried out under the project. Table 4 describes briefly field trials, and the techniques variations implemented.

Eighty-nine techniques were selected from information gathered in the three countries, where each technique was evaluated for a numerous set of criteria related with the technical and environmental performance. The evaluation framework has four main categories (environmental, technical, social, economic) and each is sub-divided on a set of elementary criteria. All techniques were scored between 0 and 4 for each criterion by the TRACC project expert’s team, as follows: 0 for not recommended; 1 for irrelevant (w/o effect); 2 for satisfactory performance; 3 for good performance; 4 for excellent performance. Each country team collected information about the different techniques and organized meetings with experts for the technique’s performance analysis. Also, the three teams had meetings to discuss and agree on criteria interpretation and definition. The field trials carried out within the project were presented at the meetings and the results discussed, focusing on the implementation difficulties on site and the environmental/technical performance.

The final grade (P) of the technique is obtained with Equation (1):

$$P = \sum_{i=1}^{n} p_i \times k_i$$

where $p_i$ is the score given to the technique in elementary criterion $i$ (-); $k_i$ is the weight of criterion $i$ (%). The sum of $k_i$ is 100%.

Table 5 lists the criteria set and weights $p_i$ considered by the project team.

For the weight distribution presented in Table 5 the environmental category has a global weight of

<table>
<thead>
<tr>
<th>Country</th>
<th>Paving technique</th>
</tr>
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</table>
| France  | – Surface dressings  
– Surface dressing with RAP (10% and >10%)  
– Hot surface dressing with RAP (>10%)  
– Surface dressings with vegetable oil based fluxed bitumen  
– Surface dressings with foamed bitumen  
Spain    | – Warm-mix asphalt  
– High-modulus warm-mix asphalt with high RAP content  
– Asphalt rubber mixtures  
Portugal | – Warm-mix asphalt  
– Half-warm recycling in plant |

<table>
<thead>
<tr>
<th>Technique</th>
<th>Place</th>
<th>Description</th>
</tr>
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</table>
| In situ cold recycling with bitumen emulsion of previously recycled asphalt layer | RD 125 Luchon FRANCE | Section 1: Base layer (recycled in 2001) recycling with rejuvenating oil addition, with a thickness of 80 mm.  
Section 2: 80 mm thick recycling; 40 mm surface course (asphalt concrete) and 40 mm recycled base layer.  
Section 3: 80 mm thick recycling; 20 mm mastic asphalt, paved before recycling, 40 mm surface course (asphalt concrete) and 20 mm recycled base layer.  
Section 4: 80 mm thick recycling; 40 mm asphalt concrete, paved before recycling, and 40 mm former surface course (asphalt concrete). |
| In situ cold recycling with bitumen emulsion | RD 20 Vendine FRANCE | 70 mm thick layer recycling with highly aged bitumen ($T_{RAP} > 77^\circ C$, using two different bitumen emulsions. |
| Cold-mix asphalt with 100% RAP | RD 20 Vendine FRANCE | Cold-mix asphalt with 100% RAP; 4 sections with different RAP aggregates gradation and emulsion combination. |
| Half-warm mix recycled asphalt with 100% RAP | CL 600 Valladolid ESPAÑA | 70 mm thick layer with half-warm mix recycled asphalt with 100% RAP (95°C). |
45%, the technical category of 20%, the social category of 15%, and the economic category of 20%. Maximum grades in each category are 1.8, 0.8, 0.6 and 0.8 respectively. From the evaluation of the techniques by the project team, the following conclusions are drawn:

- in the environmental category, which measure the emission, resource and energy impacts of the technique, in situ cold recycling, with cement or bitumen (emulsion or foamed) are considered the best; hot, warm and half-warm recycling techniques have only slightly lower grades; Spanish experts highlight also surface dressings and one asphalt rubber mixture while the Portuguese experts highlight high half-warm mix recycling with 100% RAP; high grades in this category (average 1.15) were expected due to the environmental criterion-related selection procedure;
- for the second category (technical), which is related with in-service performance and the ability to solve pavement distresses, in situ cold recycling techniques have first-rate grades; in Spain and Portugal it is considered that in plant recycling, either hot-mixing or at lower temperatures (warm and half-warm mixing), have also good performance; Spanish experts distinguish as well asphalt rubber mixes with low rubber content; in opposition, the techniques with weaker performance are surface dressings and cold mix asphalts; the higher average grade in this category for the Portuguese techniques set versus the French and Spanish set (0.53 to 0.41) may be related with the lower number of selected techniques by the Portuguese team;
- regarding the social impacts, there are notorious differences in each country evaluation; in France, the average grade is high (0.46) and it stands out positively in situ recycling and lower temperatures (warm and half-warm mixing) production techniques; in Spain, the average grade decreases to 0.35, with highlights to surface dressings and in situ cold recycling; in Portugal, the grades

### Table 5. Criteria for the evaluation of paving techniques.

<table>
<thead>
<tr>
<th>Main categories</th>
<th>Elementary criteria</th>
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<tbody>
<tr>
<td>Environmental</td>
<td>preservation of resources</td>
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<td></td>
<td>aggregates</td>
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<tr>
<td></td>
<td>binder</td>
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<tr>
<td></td>
<td>water</td>
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<tr>
<td></td>
<td>wastes reuse</td>
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<td></td>
<td>energy saving</td>
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<td></td>
<td>raw materials production</td>
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<tr>
<td></td>
<td>mixes production</td>
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<tr>
<td></td>
<td>raw materials transport</td>
</tr>
<tr>
<td></td>
<td>mixes transport</td>
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<tr>
<td></td>
<td>paving</td>
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<tr>
<td></td>
<td>gazes emissions reduction</td>
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<tr>
<td></td>
<td>broad environmental impacts</td>
</tr>
<tr>
<td>Technical</td>
<td>mechanical behavior</td>
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<tr>
<td></td>
<td>friction adherence</td>
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<tr>
<td></td>
<td>cracking</td>
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<tr>
<td></td>
<td>layers (de)bonding</td>
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<tr>
<td></td>
<td>permeability</td>
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<tr>
<td></td>
<td>bleeding</td>
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<td></td>
<td>rutting</td>
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<tr>
<td></td>
<td>longitudinal roughness</td>
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<tr>
<td></td>
<td>ravelling</td>
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<tr>
<td></td>
<td>noise</td>
</tr>
<tr>
<td></td>
<td>end-of-life ruin</td>
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<tr>
<td>Social</td>
<td>noise reduction</td>
</tr>
<tr>
<td></td>
<td>operation conditions (drivers)</td>
</tr>
<tr>
<td></td>
<td>working conditions (paving)</td>
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<tr>
<td>Economic</td>
<td>construction costs</td>
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<td></td>
<td>construction traffic damage</td>
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<tr>
<td></td>
<td>operation and maintenance costs</td>
</tr>
<tr>
<td></td>
<td>durability</td>
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<tr>
<td></td>
<td>level of recycling</td>
</tr>
</tbody>
</table>
vary between 0.25 and 0.35, with higher values to open and gap-graded asphalt rubber mixtures with high rubber content;

− in the economic category, most techniques are positively evaluated (average 0.60); the highest grades are given to surface dressings and slurry seals in France and to *in situ* cold recycling in Spain and Portugal; in opposition, grave-bitumen and grave-emulsion in France, asphalt rubber mixtures, with high rubber content, due to the initial investment value, in Portugal and Spain, have the lowest grades; nevertheless, Spain experts consider asphalt mixes with crumb rubber lightly modified bitumen a worthy investment;

− concerning global grades, cold in situ recycling techniques have the highest grades, above 3.0, followed by the techniques with mixing at lower temperatures (warm and half-warm); the lowest grades (2.0–2.4) are given to hot-recycling with low RAP content, to cold mixes and to asphalt rubber mixes (w/ high rubber content).

The social, environmental and economic impact of increasing the use of TRACC type techniques in project partner countries was studied in Working group 4 (GT4). The French team used SEVE, a commercially available software (www.seve-tp.com), to compare the environmental footprint of different techniques with the standard technique (hot-mixed asphalt), for some specific situations, based on four indicators, as follows: energy consumption (MJ); green-house gas emissions (ton CO₂ equivalent); reduction of natural aggregates consumption (ton); RAP usage (ton).

4 TRACC-EXPERT

TRACC-EXPERT is the software that was developed in TRACC project to be a guidance and decision-support tool for the road construction and management players. The software package was programmed by IFSTTAR (*L’Institut français des sciences et technologies des transports, de l’aménagement et des réseaux*) with the objective of providing the following two functionalities: ranking paving techniques considering the environmental, technical, socio and economic performance, with user-defined criteria weights; library of materials and constructions specifications, and field projects database for all techniques. The software can be ordered for free by email to traccexpert@developpement-durable.gouv.fr.

Figure 1 shows the welcome screen of the software. Information is presented in three languages: French; Portuguese and Spanish.

The software architecture was designed so that the user has various options (freedom) in the way the guidance tool and the information database are used (TRACC, 2012). The following features are available to the user:

− partial or global access to database; the user can access information from one or several countries;

− 3 different user profiles (road agency, project manager, contractor);

− global or detailed weighing of the evaluation criteria (environmental, technical, social, economic);

− construction work type: new construction; maintenance/rehabilitation; preventive maintenance;

− TRACC techniques ranking according to the user defined criteria.

Figure 2 presents a flowchart of how to use the software and options provided to the user. Regarding weighing options (*k* in Equation (1)), in global level the user defines the 4 main categories weight (0–100%) while in detailed level it is required the user to define the weight of each criterion in the 4 categories (see Table 5). Nevertheless, the user is not free to change the performance scores (*p* in Equation (1)) of the techniques that were given by the TRACC experts.

Three different user profiles were defined to adapt the information requirements to the general characteristics of different road construction players. “Road agency” profile corresponds to road network administration institutions, at the highest level of the construction process hierarchy. For this profile type, the techniques are ranked according to the defined global category weights and the construction work type, as illustrated in Figure 3. TRACC-EXPERT aids the agency to establish guidelines for their road network paving works.

“Project manager” and “contractor” refer to two entities that work together in a specific field.
The user defines first the weights distribution (detailed level) and following the characteristics of the field project, as follows:

- work type (new construction; preventive maintenance w/ or w/o structural improvement; maintenance/rehabilitation);
- climate (oceanic; Mediterranean; continental; mountain);
- traffic class;
- work area (urban; rural);
- pavement structure flexibility (very flexible; semi-rigid/bituminous; rigid);
- pavement condition (cracking; permeability; rutting; roughness; skid resistance; potholes; delamination; bleeding);
- specific objectives (driving comfort; friction/texture; noise).

For the previously defined conditions it is presented the list of techniques that can be implemented (see Figure 3). Each technique is described briefly and the grade obtained in all categories is presented. In addition, the user has access to the technique datasheet with information about the evaluation procedure, the construction method, the environmental report and, also to data from some field projects where the technique was used.

![Figure 2. TRACC-EXPERT—flowchart.](image_url)

![Figure 3. TRACC-EXPERT—Example of the techniques list.](image_url)
Figure 4 shows an example of the data provided to the user which, in this specific situation, was collected in France from some field projects where warm mix asphalt w/ up to 10% RAP was used.

The information that is provided is intended to help contractors identify/assess investment options in construction method/techniques, with less environmental impact, in accordance with the road agencies strategy.

At the end of the analysis, a report is automatically prepared that summarizes information initially provided and the results from TRACC-EXPERT which helps the analysis by other players involved in the project.

5 Conclusions

In the world public opinion, the construction industry is labeled with the destruction of the environment and the unbalanced consumption of natural resources, including energy. In Europe, the European Commission has approved ambitious goals for the reduction of energy consumption and greenhouse gases emissions by 2020. Taking inspiration from these challenges, a cooperation and technological development project, named TRACC, was established with different road construction players from France, Spain and Portugal. There are many environmental friendly paving techniques, but with different levels of experience among European countries/regions. The techniques evaluation over 4 domains (environment, technical, social and economic) was carried out based on local experience and field tests data (some carried out under the project).

The project outcome is TRACC-EXPERT, a software tool, which may be used as a library of paving techniques with data from field tests and monitored road sections, and a tool to rank available paving techniques according to sustainability performance, considering user preferences and job site specific conditions. It is expected to help road players, from an area over than that participated in project, have more sustainable and informed decisions.

Acknowledgment

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REFERENCES