TYROSAFE (TYRE AND ROAD SURFACE OPTIMISATION FOR SKID RESISTANCE AND FURTHER EFFECTS)

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ABSTRACT

The project ‘TYROSAFE’ (Tyre and Road Surface Optimisation for Skid Resistance and Further Effects) was a coordination action funded by the European Community’s seventh framework programme (FP7, 2007 - 2013). The main objectives of the project were to raise awareness, in order to coordinate and prepare for European harmonization of skid resistance policies and to optimize the assessment and management of essential tyre/road interaction parameters, within the broader context of increasing safety and reducing the impact of European road transport. To achieve this, the project focussed on tyres, the road surface, and the interaction between the two, because only an optimized interaction can deliver road safety benefits and simultaneously ensure the most positive greening effect through reduction of CO2 output and noise emissions.

The project provided a synopsis of the current status of scientific understanding in these areas, the application of this knowledge in National and European standards, and existing skid resistance measurement policies, methods, and parameters. This allowed future research requirements to be identified, and a proposal made with regards to the future objectives of European road administrations in order to optimize three key properties: skid resistance, rolling resistance and tyre/road noise emission.

INTRODUCTION

The project ‘TYROSAFE’ ((Tyre and Road Surface Optimisation for Skid Resistance and Further Effects) was a coordination action funded by the European Community’s seventh framework programme (FP7, 2007 - 2013). The duration of the project was from Beginning of July 2008 till the end of June 2010, thus 24 months. The partners within this project came from institutes of 7 different European Countries. These were AIT (Austrian Institute of Technology) from Austria (Project Coordinator), BASt Federal Highway Reseach Institute) from Germany, FEHRL (FEHRL AISBL) from Belgium, LCPC (Laboratoire Central des Ponts et Chaussées) from France, RWS DVS (Rijkswaterstaat Dienst Verkeer en Scheepvaart) from Netherlands, TRL (TRL Limited) from United Kingdom and ZAG (Zavod Za Gradbenistvo Slovenije) from Slovenia.

The main objectives of the project were to raise awareness, in order to coordinate and prepare for European harmonization of skid resistance policies and to optimize the assessment and management of essential tyre/road interaction parameters, within the broader context of increasing safety and reducing the impact of European road transport. To achieve this, the project focussed on tyres, the road surface, and the interaction between the two, because only an optimized interaction can deliver road safety benefits and simultaneously ensure the most positive greening effect through reduction of CO2 output and noise emissions. The concept of the project is summarized in Figure 1 – the aims were to identify (existing) best practise, develop new solutions & technologies, adoption & harmonisation as well as sharing the gathered knowledge and raising awareness on the objectives of the project.

Figure 1: Concept of the TYROSAFE project.

Within this range TYROSAFE created synopses of previous activities, compiled the available expertise into reference documents, designed recommendations, guidelines and roadmaps for future activities and projects as well as identified knowledge gaps in order to optimize three key properties of road surfaces: skid resistance, rolling resistance and tyre/road noise emission.

The work within the project was carried out in the following six work packages (WP):

- WP1: Policies of EU countries for skid resistance / rolling resistance / noise emissions
- WP2: Harmonisation of skid resistance test methods and choice of reference surfaces
- WP3: Road surface properties – skid resistance / rolling resistance / noise emission
- WP4: Environmental effects and impact of climate change – skid resistance / rolling resistance / noise emissions
- WP5: dissemination and raising awareness
- WP6: Management.

Thus this partition makes it possible that each topic of the 4 technical work packages WP1-4 (policies, test methods, surface properties and environmental effects) can be handled separately as well as benefit from the results of other work packages or feed other work packages. The interaction of the work packages is demonstrated in Figure 2.

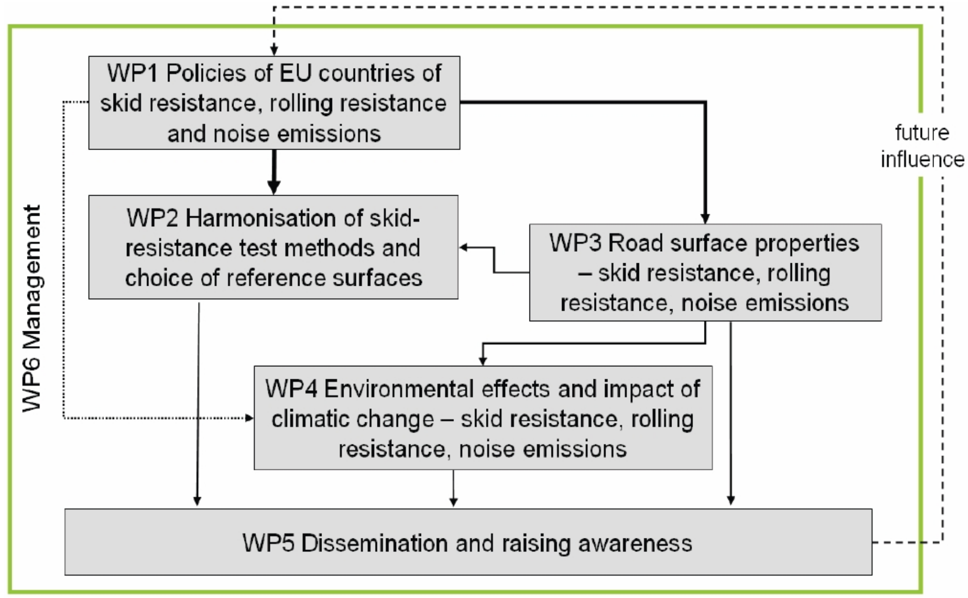

Figure 2: Work packages and their interaction.

BACKGROUND AND OBJECTIVES OF TYROSAFE

Road traffic in Europe and also on any other place in the world plays a key role in providing mobility and flexibility to the economy and individual citizens. Road surfaces have an important, but often underestimated role in the functioning of this vital transportation network. However, research has shown that an optimisation of road surface properties can be used to achieve increased safety and reduced environmental impact of road traffic.

Drivers need sufficient grip between the tyres and the road to accelerate, decelerate or change the direction of a moving road vehicle. Grip is provided by the skid resistance properties of the road surface in combination with the friction characteristics of the tyre. This combination is critical for safe driving and many countries have investigated the correlation of a low skid resistance level with accident hot spots as well as the reduction of crashes by improving skid resistance. With a sufficiently high value of skid resistance the safety of roads can be improved and the number of accidents can be reduced.

Therefore skid resistance is a very important characteristic of the road surface influencing safety particularly because it can be improved by the design of the road surface. Yet a harmonised European scale for the measurement and assessment of skid resistance still remains to be developed. In addition to that the national policies for managing road surface properties like skid resistance differ considerably across the EU, which again makes it more difficult to provide a comparable level of safety and environmental impact all over Europe.

Environmental questions like noise pollution, air quality and energy consumption are becoming more and more important, and therefore any consideration of the safety benefits of improved skid resistance needs to focus on rolling resistance and noise emissions as well. Rolling resistance has to be overcome for vehicle propulsion and therefore low rolling resistance leads to reduced fuel consumption which in turn results in reduced CO2 and air pollutant output. The noise emission of road traffic is currently dominated by tyre/road noise in the speed range above 30-50 km/h. Recent research and development has provided more silent road surfaces, however, the necessary changes in the road surface structure may engender target conflicts with other vital parameters. Currently the properties of road surfaces and tyres are not optimised to balance all of these properties evenly. Knowledge of how they interact with each other is very limited.

Moreover, the policies and standards of individual countries relating to skid resistance, rolling resistance and noise emissions vary considerably across the EU. Despite some previous activities there is a need to bring ideas together and establish what scope there is for developing a harmonised approach for the future.

RESULTS OF THE TECHNICAL WORKPACKAGES

The following subchapters summarize the objectives, the results and findings of the four technical work packages concerning policies, harmonisation of skid resistance test methods, road surface properties as well as environmental effects an impact of climate change.

WP1: Policies of EU countries for skid resistance / rolling resistance / noise emissions

This Workpackage focused on the various policies in European countries concerning skid resistance, rolling resistance and noise emissions. Due to the fact that throughout the European countries different approaches exist to ensure appropriate skid resistance for newly built and also existing roads, in a first step the existing policies and standardisation work concerning the three key properties within the European countries were reviewed. In a next step the different policies were compared and advantages / disadvantages of the current as well as alternative approaches were considered.

Currently, policies on skid resistance exist on national level only, moreover they are dependent on the road class (see Figure 3). There is no formal EU policy issued today, but skid resistance is still considered as an important surface property. There are also different measuring devices in use. Figure 4 summarizes the numbers of countries using each of the 15 different devices identified to measure skid resistance on policy issues.

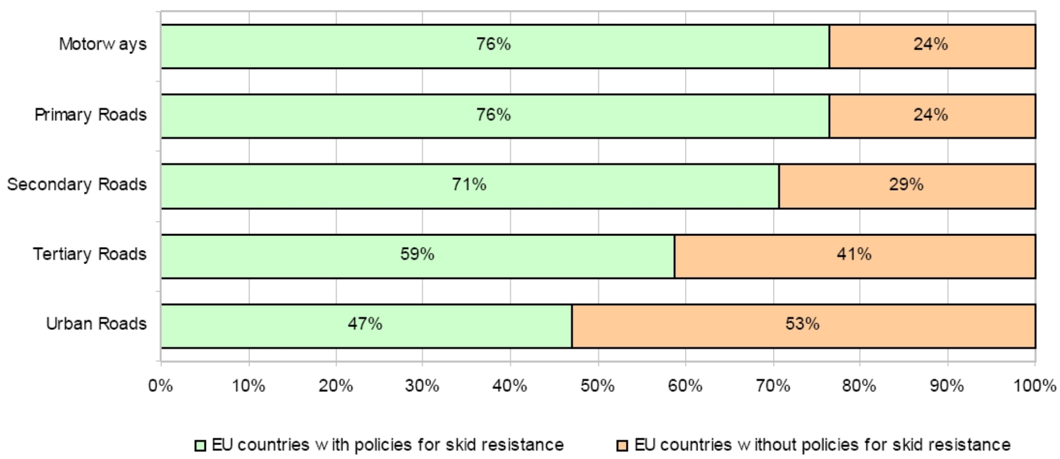

Figure 3: Shares of EU countries with and without policies for skid resistance per road class

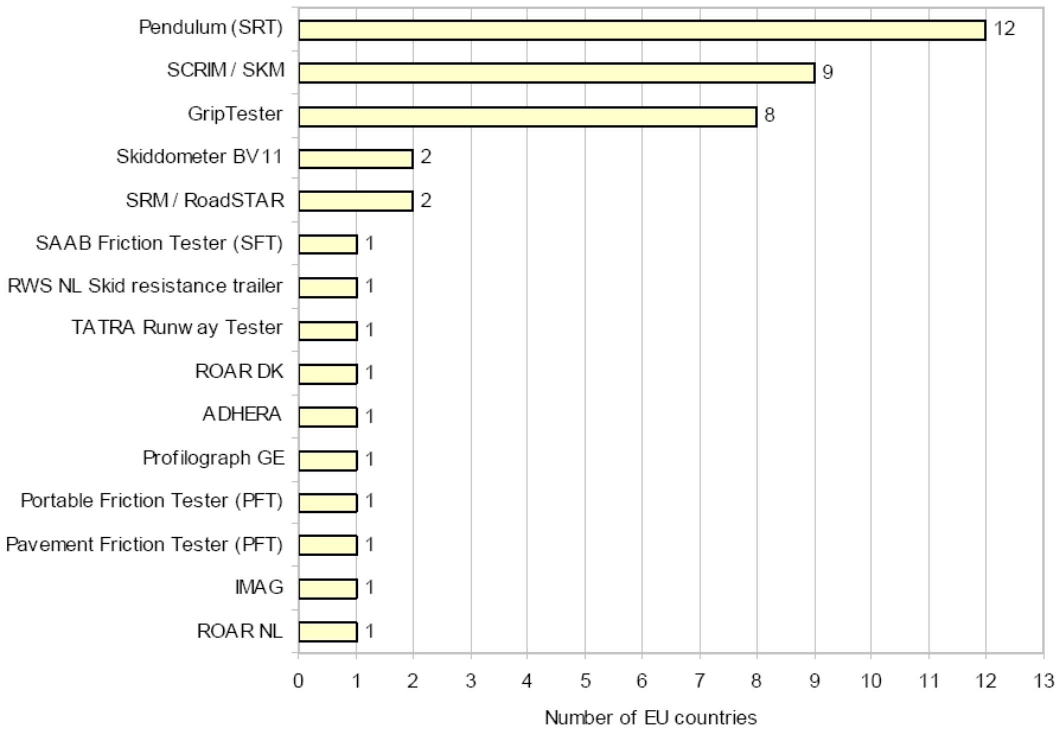

Figure 4: Skid resistance devices and the number of EU countries using it on policy issues

About noise emission there are existing EU policies; e.g. Directive 70/157/EEC – emission limits; Directive 2002/49/CE – environmental noise (noise maps for large road infrastructures, equal noise areas, source of noise, number of people affected, no limits/thresholds defined),Directive 2001/43/EC – tyre rolling noise (noise limit values, test procedure, evaluation shows that limits could be stricter) and noise measurements are standardized (Pass-by-Method (SPB, CPB)) or standardization is ongoing (Close proximity Method (CPX)).

The results of the questionnaire also show that for rolling resistance there is no European regulation and no national regulation. There are also no national thresholds for rolling resistance of pavements, but 50% of the questionnaire answering countries are aware of fuel/CO2 saving potential. To measure the rolling resistance of road surfaces and of tyres there are different devices in use. These devices are drums (inner and outer drums), trailers and also special equipped cars to measure the rolling resistance indirect via fuel consumption.

The following recommendation for future harmonised policies based on the results of the questionnaire and findings by the TYROSAFE team were elaborated:

Skid resistance:

- The policy will be set at EC level through CEDR or CEN and implemented in each country by their national road authorities.
- The harmonised policy should apply to Level 1 and Level 2 networks (motorways and principal roads linking major towns).
- Policy applies to in-service roads.
- Policy does not apply to new asphalt surfacing (early life skid resistance is not covered).
- The measurement technique will be defined based on the following principles: Continuous measurement using a device for which there is an established standard (e.g. a CEN TS).
- For in-service roads, the network should be monitored every year; maximum: 3 years; in both directions.

- For normal network assessment purposes measurements will be averaged over not more than 100 m for comparison with thresholds.
- Threshold levels will be based on the risk of skidding on different types of sites with the overall objective of equalizing skidding accident risk across the network.
- On in-service roads: when the threshold is not met, prioritized investigation will be used to establish whether improvement to the skid resistance at that site would be worthwhile and should be programmed.

Noise emission:

- EC sets a model policy, Road Authorities (national, regional, urban or private company) implement the policy and fix the thresholds.
- The harmonised policy should apply to all kinds of networks but concentrated on areas exposed to road noise.
- Measurement technique will distinguish between road surface classification, assessment of a new surface and monitoring of networks over time.
- A classification method will be defined for noise prediction models and to prescribe low noise surfaces.
- Measurements for assessing new surfaces for contractual purposes will be recommended.
- For in-service roads, the network can be monitored annually.
- Measurements will be adjusted to a standard reference speed–critical issue for noise!
- On new road surfaces: where a threshold is set for contractual purposes on a new surface, when the threshold is not met individual countries will set their own choice of actions.

Rolling resistance:

- The policy will be set by the EC through CEDR or CEN and implemented in each country by their national road authorities.
- The policy should apply to Level 1 and Level 2 networks (motorways and principal roads linking major towns).
- In-services roads: monitoring intervals to be defined
- Measurements for assessing new surfaces should be made (including definition of actions to be taken when thresholds are not met)

Concerning rolling resistance, there are some key activities which need to be done before a harmonised policy could be set. Some of these activities are for example defining a reference surface (e.g. according to ISO10844), defining a reference tyre (e.g. SRTT or smooth tyre), defining measurement technique (e.g. based on established standard (e.g. ISO), defining test speed), research to establish a reference rolling resistance coefficient (for comparison of performance of roads) and also research on texture and evenness may allow texture parameters to be used as an alternative to direct rolling resistance monitoring.

WP2: Harmonisation of skid resistance test methods and choice of reference surfaces

Within this work package the state of the art of skid resistance test methods, existing specifications and standards in EU countries and around the world are analysed. Furthermore previous harmonisation experiments (e.g. PIARC experiment, HERMES etc.) and CEN TC 227 WG5 harmonisation strategy proposal were synthesised. Based on the results of the previous harmonisation experiments (e.g. PIARC, HERMES) and the existing skid resistance test methods a harmonisation method was suggested and furthermore a road map as well as an implementation plan with specific steps until the final harmonisation policy was developed.

During the 1st step twenty-three devices were identified from Technical Specifications from CEN and from project partner sources. All of these devices can be classified into one of three groups depending on the principle used. These three groups/principles are: fast moving & measuring longitudinal friction coefficient, fast moving & measuring side-force friction coefficient and stationary or very slow moving devices. Some of these devices such as SCRIM/SKM, GripTester and SRT (pendulum tester) which are built commercially and marketed across the world are used in many countries and in large fleets, other devices are unique and only used in the country in which they were made.

The review of previous skid resistance harmonization projects has found that there have been a number of attempts to establish methodologies and common scales to harmonise measurements from different skid resistance devices. Although some progress has been made, there is not yet a scale or system that can harmonise the range of devices currently used in Europe with sufficient precision to be of practical application with widespread acceptance. There is scope for further research into ways of improving the processes and these are considered in the "road map".

The concept of the previous skid resistance harmonization projects was to find a "Common Scale" that would represent the skid resistance condition of the road under defined "reference" test conditions. A generalized conversion formula would then be used to convert measured values from individual machines under their particular test conditions to equivalent values for the reference conditions, that is, on the Common Scale. The Common Scale was based on reference levels derived from measurements of texture depth and the average friction value from a set of "reference" skid resistance devices that measured different surfaces at different test speeds. The main difficulty that these projects encountered was finding a mathematical model that could satisfactorily convert actual values to their equivalents on the Common Scale under the widely differing measurement principles and operating conditions used in practice. This, compounded by issues related to the quality control of some machines, meant that the reproducibility of measurements expressed on the Common Scale was unacceptably poor.

The work therefore focused on ways to define the Common Scale that would improve its accuracy but still allow current measurement devices to be used. Various approaches were considered, starting from the "average of all devices" approach used in PIARC and HERMES, but with better-developed conversion models, through using a smaller set of measurement device types (the reference fleet) to set the Common Scale, to full standardization by simply imposing the use of one device type across the EU.

These three possible destinations are proposed in the developed road map (see Figure 5) as follows: a Harmonised EU System, in which all current devices (within the limitations of their accuracy classes) continue to be used, with the Common Scale being applied for the various uses of skid resistance data across Europe; Full Standardization, a longer-term possibility in which only one device type is used across the EC; Optional Use of Common Scale where use of the Common Scale and conversion formulae is not an EU requirement but countries can opt to use the scale to harmonize their internal measurements or with neighbors should they so choose.

With the road map there are four possible routes (see Figure 5) to achieve the Common Scale which differ in the way in which the reference level for the Common Scale is established. The options are designed to progressively improve the potential accuracy. Route A is based on using all existing devices to define the Common Scale, Route B reduces the set of reference devices to those that operate on similar principles, Route C goes further and limits the reference fleet to devices of one specific type only. Route D is the final level, using just one machine to set the Common Scale reference level. Here there are two branches, one using an example of an existing device type, the other using a purpose-designed new device type. All the routes make provision for writing supporting documents and quality procedures, together with establishing accreditation processes to maintain the accuracy and stability of the Common Scale in the longer term. For each of the four routes a full explanation with regard to accuracy, advantages and drawbacks was worked out.

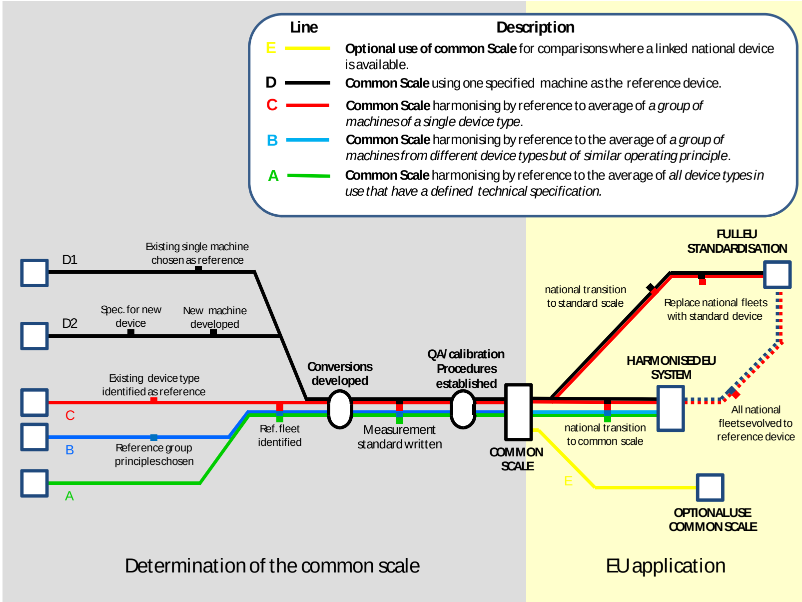

Figure 5: TYROSAFE "road map" for harmonisation of skid resistance test methods

WP3: Road surface properties – skid resistance / rolling resistance / noise emissions

The objectives of work package 3 were to describe different parameters of road surfaces and tyres which are relevant for skid resistance, rolling resistance, noise emission, to identify interdependencies between these parameters with regard to the road surface properties, to make recommendations for optimisation the interaction of road surfaces and tyres and finally to identify the lack of knowledge and make proposals for further research.

Concerning the road surface properties there are discussions in various groups (e.g. tyre engineers, vehicle engineers and road construction engineers as well as road users and road agencies) from different perspectives, because of different interests and therefore different ways to optimize each of these three properties. Based on the different ways of optimizing an interdependency matrix for road surfaces and tyres was worked out. These matrixes show the interaction and the impact of changes of various parameters on all three road surface properties. The following figure (Figure 6) list some of the parameters while production of road surfaces which will have an impact on at least one road surface properties, but beside these parameters there are additional parameters like environmental parameters and traffic interaction which will also have an impact on the surface parameters and therefore on the road surface properties (see Figure 7). Some of these parameters can be influenced like mix design or constructions while others such as environmental parameters and traffic interaction can't be influenced. The developed interdependency matrix summarizes all possible road surface parameters and shows the impact (e.g. positive impact, negative impact, no impact or impact unknown) on the three road surface properties. Therefore the interdependency matrix can show conflict areas while trying to optimize all surface properties simultaneously.

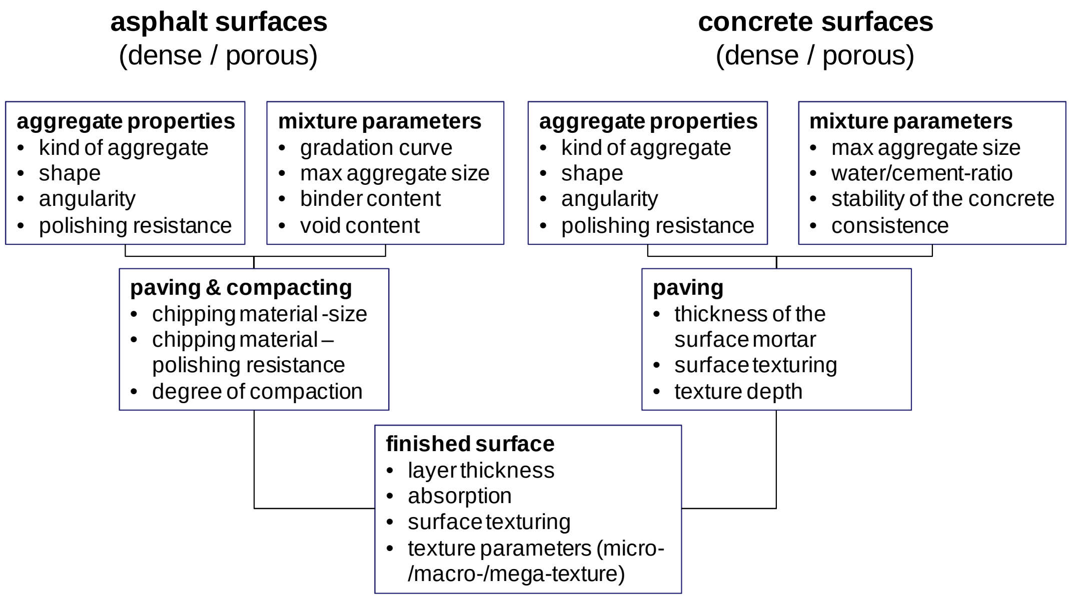

Figure 6: Road surface parameters with an impact on the road surface properties

Figure 7: Parameters influencing the three surface properties (skid resistance, rolling resistance and noise emission) from the perspective of the road surface

The interdependency matrices show the different impact of various parameters from the surface and tyre point of view on the road surface properties. These matrices were developed separately for surface parameters and for tyre parameters, because a matrix which combines surface and tyre parameters would be too complex to show all possible interactions. Therefore a matrix for showing the impact of the surface parameters and a matrix for the impact of tyre parameters on the road surface properties were developed. Within each of these matrices there are areas where the impact of the parameters on one or more road surface properties is not known. These are the so called knowledge gaps, which lead to the need of further investigation. The research needs which were formulated within this work package are divided in thirteen main research areas which comprise surface parameters (including measuring systems), tyre parameters (including measuring systems) and surface/tyre interaction - simulation models and cover a period of 20 years. The research steps were clearly defined because some tasks must be completed before others can begin since later work depends on the outcomes. Some work will need to be carried out in clear phases, with defined components in each, that move progressively from laboratory studies through to the stage where the results can be applied practically.

Currently the main research problems are that surfaces and tyres are optimised separately. The surfaces are tested with specified methods with regard to skid resistance, rolling resistance and noise emission and thus the surfaces are optimised according to the test methods. Normally the tyres are tested on specified surfaces and often artificial surfaces (e.g. according to ISO 10844), but not on real surfaces. But the biggest problem currently is that normally surfaces and tyres are optimized mostly with regard to only one of the three road surface properties.

WP4: Environmental effects and impact of climate change – skid resistance / rolling resistance / noise emissions

Within this work package environmental implications of optimising skid resistance were analysed, potential impact of climate change were considered and finally areas for future research on environmental effects were identified. The two main strands were the influence that providing harmonised/optimized skid resistance could have on the environment and the effect of climate change on skid resistance.

The implementation of increased skid resistance requirements in some countries may lead to an increased consumption of more polishing-resistant aggregates. This could generate greater transport emissions as suitable aggregates can only be obtained from a limited number of quarries and as a result may be transported over greater distances rather than using local aggregates with lower PSV. The increased skid resistance requirements will also lead to increased tyre wear and therefore to increased particle emissions as well as to increased rolling resistance and thus to higher fuel consumption, higher GHG1 and other exhaust emissions. Higher skid resistance requirements could also induce an increased texture depth which will lead to an increase in noise emissions. But on the other hand such a requirement could also lead to reduced road maintenance.

Concerning the strand two concerning the effect of climate change different studies were analysed with regard to the various scenarios and the impact on temperature and precipitation. Various studies on temperature and precipitation effects show that skid resistance, noise emission and rolling resistance decreases with temperature and on wet surfaces the skid resistance decreases while noise emission and rolling resistance increases.

The results of this work package show that much is already known about the environmental effects associated with road/tyre interaction and the potential impact of climate change on roads and tyres, but however there are still knowledge gaps that need further investigation and raise areas for future research. These areas were divided in three areas related to skid resistance policy, rolling resistance policy and noise emission policy. Concerning the skid resistance (safety) policy the focus should be on aggregate resourcing / consumption, the impact of particulates and contaminants on tyre/road surface interaction, the polishing process and on monitoring the changes to seasonal variation in skid resistance (e.g. increased understanding of the climate parameters which cause such changes).

IMPLICATIONS FOR SOCIETY

The last chapter reviewed the results and findings of the technical work packages of TYROSAFE. In contrast this chapter summarizes the likely social implications which can be expected if the project's recommendations are adopted.

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[1] GHG - Green House Gas

Improved road safety

Under the heading of improved road safety, the most important and most obvious direct benefit of implementing the findings of TYROSAFE is the reduction in the numbers and severity of road traffic accidents, leading to a reduction in deaths and injuries as well as other consequential costs. Some other societal benefits are as follows:

- Harmonisation of skid resistance policies and measurements will help countries with no guidelines or that have no background in measuring skid resistance with the start they need in monitoring skid resistance on their road network. Harmonised policies could also lead to an increase in skid resistance requirements in some countries. In such countries less maintenance could be required as skid resistance should remain higher for longer. This will also lead to a reduction in the environmental impacts associated with maintenance.
- Harmonisation of skid resistance could result in changes to policy in relation to the specification or procurement of surfacing materials. For example, highway authorities might introduce certificates of production and quality schemes, which are often based on a material or system's performance rather than its constituents.
- For questions of road safety performance, the project's findings offer the possibility of bench-marking by defining a minimum required level of road safety regarding friction supply and demand.
- With harmonised measurements, EU road authorities, surfacing contractors and material suppliers would have a consistent way of specifying and verifying the acceptability of new surfacings. Road authorities who already monitor skid resistance but wish to compare standards with others based on different measurement methods would have a convenient tool for doing so.
- TYROSAFE provides the possibility of knowledge transfer between road owners, tyre manufacturers and the road construction industry on how to achieve greater road safety by means of optimized pavement design and optimized tyres.
- One of the top priorities of the EU is in the breaking of barriers and opening of internal markets, with potential for increased cross-border travel of people and goods. Harmonisation of policy relating to the key properties would make the situation on the road more predictable for the user and ease comparison of safety levels between countries.

Greener Transport

Vehicle fuel consumption is strongly linked to tyre rolling resistance which is influenced by the road surface characteristics. TYROSAFE has studied the influence of tyre-road interaction on rolling resistance and the most obvious benefit of its findings is a reduction of the rolling resistance as a result of choosing the optimal tyre/road combinations.

This has a positive effect in reducing fuel consumption and hence a decrease in CO2 contribution. Further, reduced fuel consumption would reduce other greenhouse gas emissions. In addition to reducing fuel consumption, GHG and other exhaust emissions, low rolling resistance roads could also reduce tyre wear and the generation of particulates. As well as reduced local pollution, fewer particulates mean less clogging of porous surfacing, so such surfacings require less cleaning and retains their noise-reducing properties for longer.

Other important societal benefits are as follows:

- Optimized pavements and tyres need less maintenance, which decreases the amount of raw materials consumed and energy used in production and also leads to a reduction of disposal problems.
- As mentioned earlier, implementation of TYROSAFE findings will lead to fewer accidents and, as a consequence, less congestion, which itself means a reduction in fuel consumption and associated pollutants.
- Harmonisation of rolling resistance measurements will offer the possibility of bench-marking by defining the maximum permitted level of rolling resistance.

Improved health conditions

There is no doubt that noise causes or contributes to a number of severe health consequences (see Chapter 0). Noise exposure has also been known to induce tinnitus, vasoconstriction and other cardiovascular impacts. Beyond these effects, elevated noise levels can create stress, increase workplace accident rates, and stimulate aggression and other anti-social behaviours. Traffic noise is one of the most significant causes for every day noise. Reduced traffic noise by optimising tyre/road interaction potentially has a strong beneficial impact on peoples' health.

The TYROSAFE study provides the possibility to use a better understanding of the noise emission process in order to create low noise tyre-pavement combinations and to reduce the traffic noise at source. Additionally the project's findings provide the necessary information to define a maximum allowed level of traffic noise which will result in the transfer of a future bench-mark into practice. This will also contribute to better cooperation between the tyre and road industries.

CONCLUSIONS

The results of the project include a thorough evaluation of the role of the key road surface parameters skid resistance, rolling resistance and noise emission of road surfaces in the context of the European road transport system including their interdependencies and the interaction with the climate.

TYROSAFE has managed to provide an overview of the state of the art and of the remaining knowledge gaps to be closed, as well as recommendations for managing essential road surface properties. A possible way to the future harmonisation of policies and assessment methods has been shown. The implementation of the proposed policies and systems will finally depend on decisions made by stakeholders in road transport like road administrations and transport ministries, which go beyond the scope of this project.

Common and compatible assessment management of road surface parameters in Europe will in turn provide more safety and reduced environmental impact. Wider implications are the reduction of accidents and the reduction of CO_2, air pollutant and noise emission from road traffic. This will benefit both the European economy and the general public relying on road transport as an efficient, safe and ecologically sustainable transportation system.

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Gernot Schwalbe is automotive engineer; working at BASt (Federal Highway Research Institute (Germany)) as senior researcher in the section vehicle pavement interaction and responsible for measurements of tyre road noise emissions and rolling resistance. He was respectively involved in several national and international research projects about tyre road noise and rolling resistance (e.g. TYROSAFE, SILENCE, LeiStra2).

Manfred Haider is responsible for the topic of Traffic Acoustics in the business field Transport Infrastructure Technologies of AIT in Vienna. He works in the field of traffic noise measurements, tyre/road noise, performance characteristics of noise barriers, integrated noise abatement systems, and active noise control. Manfred was involved in several EU-projects (e.g. SILENCE, SPENSE) and he was the coordinator of the TYROSAFE-project.