3.1 Publishable summary

Today’s cars represent a complex compromise between contradictory requirements with regard to safety, exhaust emissions, noise, performance and price. However, since the quality of life, particularly in the urban environment, is heavily influenced by air and noise pollution resulting from road traffic, one of the top priorities for car manufacturers is the reduction of noise and emissions from vehicles, with particular attention currently being focused on CO₂. In this regards, the principal vehicle manufacturers in Europe have unanimously agreed to adopt an integrated approach which has as cornerstones the development of more fuel efficient power trains and weight reduction of the vehicle body.

Regarding the power train, engine downsizing represents the most direct and cost effective approach to improving fuel efficiency in road vehicles in order to ensure significant reductions on the impact on the environment while still providing acceptable levels of performance and vehicle ‘fun-to-drive’. However this new generation of engines, while being ideally suited to city vehicle applications, can result in a perceivable degree of deterioration in terms of noise and vibration when compared with the vehicles currently on the market. Similarly, the mass reduction required to lower CO₂ emission and fuel consumption can lead to considerable augmented noise levels, which should be adequately compensated by integrated, light noise abatement means.

Improvement of vehicle noise and vibration without affecting other performances is proving to be extremely difficult if not impossible with state-of-the-art technology. Frequently, new technologies in the fields of smart materials and active control provide potential solutions but have only been proved in the laboratory.

The scope of Green City Car is therefore to develop flexible, integrated passive and active solutions which will not only permit noise and vibration to be attenuated in new vehicles equipped with the next generation of highly fuel-efficient power trains but enable vehicle design guidelines to be defined in order to reduce weight without compromising on comfort and safety.

During the project, city car prototypes will be realised featuring pioneering technology aiming to push its environmental-friendly characteristics to a new level. The starting point will be a next-generation city car with an innovative architecture which will be further improved within this project using frontline technology. In particular the car will be equipped with the newly developed twin-cylinder engine, developed by Fiat Power Train Technologies, which will provide very significant gains in terms of reducing fuel consumption and, as a consequence, CO₂ emissions. The concept behind this new engine is the downsizing from a conventional 4-cylinder engine to a 2-cylinder turbocharged engine in order to minimise weight (20%), reduce mechanical losses and to optimise the combustion efficiency. In addition the power train will be equipped with the innovative Multiair electro-hydraulic valve actuation technology introducing further advantages in terms of fuel consumption. The vehicle will be provided with the latest technology in terms of safety aspects related to pedestrian’s impact and car-to-car compatibility, which are of major importance in an urban environment. The noise reduction technology to be developed and implemented on such a city car will be oriented to a decrease of mass of the complete sound packages, using new materials, passive or active piezo-electric or electro-magnetic patches on vehicle and engine panels, smart Helmholtz resonators, broadband active noise cancellation. A complete integration and correct balance of such components should be found out, in order to achieve the given objectives of noise and weight reduction. Further improvements will be pursued through the development of new tyres aiming at the reduction of noise and rolling resistance. The
innovation lies in the novel design process rather than in the tyre itself. Conventional tyre design is the result of a trade-off between many conflicting performance criteria such as handling, wear, grip, rolling resistance and noise. In this project the centre of gravity of the design process will be shifted towards rolling resistance, airborne noise and reduced structure borne sound transfer towards the passenger compartment in view of lightweight vehicle and suspension structures.

On the basis of this application, *Green City Car* poses a series of specific technical objectives, the fulfilment of which will be demonstrated using prototype vehicles which include:

- **Definition of design guidelines for reducing vehicle weight by adopting integrated solutions for noise and vibration attenuation.** Results will include lightweight passive noise and vibration control solutions and design rules for lightweight vehicles incorporating integrated noise and vibration control.

- **Development of advanced, integrated solutions for noise and vibration control of vehicles equipped with energy efficient power trains;** the aim is to demonstrate that nominally one solution, appropriately tuned, can be used to control the noise and vibration in vehicles which may be equipped with a range of different propulsion systems.

- **Analysis of comparative cost benefit of new approach for integrated noise and vibration control with respect to the conventional approach to vehicle design for acceptable vibro-acoustic performance;** Deliverables will include a business case study, analysing the cost-benefit potential of the solutions developed and identifying the lead markets which will enable significant market penetration over the medium-term (3-5 years).

Pursuing the different concept in a holistic approach, *Green City Car* aims to demonstrate the feasibility of applying active systems to NVH-related problems of advanced power trains from a system point-of-view. This holistic approach should lead to a reduction in noise and vibrations levels in the order of 10 dB(A) and more measurable in the city car provided (not on component level).

In order to meet the challenges arising from the new markets in Asia and the policies defined world-wide to meet global demands such as CO₂ emission reduction and energy efficiency, light weight design, high efficient engines and efficient use of energy within the vehicles including actively controlling the NVH properties are among the world-wide most important technologies trends to be addressed by the transport industry. *Green City Car* is contributing to these challenges by its objectives of developing a holistic approach of controlled NVH properties of city cars with energy efficient power trains, thus enabling to relieve system weight (e.g. damping materials), to save energy consumption and finally reduce CO₂ emissions as well as to increase the comfort. The latter is of major importance for the customer acceptance of city cars with energy efficient engines including fully electrical drive trains.

The integrated approach considered in *Green City Car* will result in reduced weight by saving additional acoustic and vibration control treatments as well as increase the customer acceptance of environmental friendly engines including fully electrical vehicles. The final implementation and validation of passive and active measures for noise and vibration control as well as advanced low noise tires for city cars will demonstrate the potential and technological maturity of the considered solutions. This will impact / support the introduction of technologies for rationalized used of energy and CO₂ emissions reduction in the European automotive industry.

In the first reporting period the focus was on the adaptation and elaboration of enabling technologies to the requirements of city cars. In three work packages specific concepts for suitable actuators, new material systems and innovative tyres were developed and validated
on laboratory-scale. With respect to actuating principles, shunted piezo ceramics, concepts for inertial mass actuators and electro-mechanical actuators, adaptive Helmholtz resonators and the associated control strategies were considered. These selected principles were build-up as functional prototypes and validated and simplified structures. It could be proven that all concepts are feasible for the implementation in city cars which is foreseen in the second period. As test cases the lightweight suspension bracket, the torque-roll-restrictor, the intake system, engine components and the cabin has been selected.

With respect to materials, a new type of constrained layer damping treatment based on a thin aluminium foil applied on a new special type of bituminous layer has been developed. This treatment is expected to positively impact on the weight of the final damping package to be made on the demo vehicle, possibly with an added damping performance given by the usage of a constrained layer in the place of a single layer. Furthermore lightweight acoustic treatments for the sound package has been investigated combining low weight and good acoustic properties (i.e. acoustic absorption and/or insulation performance) for engine bay applications. The first material is a glass-free lightweight foam showing good formability and thermal stability properties combined with high acoustic absorption. This material is suitable for engine bay applications like hoodliner or dash outer. This foam outscores the acoustic absorption performance of melamine foam, and compares very well to that of glass wool with the same thickness and 70% less weight. A second material is a new fiber-based material for high temperature applications providing a remarkably good combination of stiffness and acoustic properties, together with high durability and thermal stability. A particularly effective combination has proven to be the double layer made of the fiber-based material as a lightweight and stiff thermo-acoustic carrier and the lightweight foam as an acoustic absorber. The acoustic absorption of such a double layer is remarkably high (above 70% from 630Hz). All developed materials were prototyped and validated.

Finally, different designs of tyres for city cars have been developed in an iterative process. A tyre construction was found with both low rolling resistance, good acoustic comfort and an acceptable interior noise, however this construction is not on target regarding the handling performance. In the next phase this tyre design will be further optimised.

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