Sustrail: The Sustainable "Freight vehicle-Track" system

[by Donato Zangani, Clemente Fuggini, Isabelle De Keyzer]

A sustainable and efficient freight transport in Europe plays a vital role in having a successful and competitive economy. Freight transport is expected to grow by some 50 % (in tonne-kilometres) by 2020 when more freight and more passengers will have to travel by rail to meet Europe's short, medium, and long-term traffic needs. In this context, rail transport is unique in its complexity. It is the only transport sector that must consider the vehicle, the transport medium (e.g. the track), and the network (flows, regulations, procedures) in parallel. Rail transport is also unique in the diversity of operating procedures, codes, regulations, guidelines, and business models across EU member states. Change for the rail industry is both necessary and opportunistic. Within this framework, the EU project SUSTRAIL was launched in June 2011, aiming at contributing to a new era in the rail freight sector by adopting a holistic approach, implementing a clear methodology and viable procedures for a combined improvement in both freight vehicles and track components.

Project objectives

The expected benefit from the SUSTRAIL project is an increased performance of the whole rail freight system (vehicle plus track), which is assessed and quantified through the implementation of appropriate life cycle cost analyses. SUSTRAIL will therefore promote modal shift of freight in Europe from road to rail, providing the approach, structure, and technical content to support this modal shift through improvements in the railway freight system including innovations in rolling stock and track components. Selected routes have been identified across three European countries (UK, Bulgaria and Spain) that have been investigated in terms of capacity, type of freight vehicles and characteristics of the infrastructure. This made it possible to define a benchmark that will be used to compare and assess the benefits of the SUSTRAIL proposed upgrades both on vehicles and infrastructure. As part of this approach, and in line with the aim of upgrading existing railway systems, an innovative freight vehicle is being designed considering two configurations: 'Conventional' (optimised with respect to existing) and 'Futuristic' (technologies not yet been proven in the railway field). Moreover, on the other side of the wheel-track interface, performance-based design principles and complementary monitoring tools are identified which can increase reliability and safety levels of the infrastructures. Achievement of this goal will assist the infrastructure managers to move towards the zero maintenance ideal for the track system. Business cases have been set up to demonstrate on real routes the contributions, solutions and innovations SUSTRAIL is aimed at introducing in the railway sector. In what follows, the major achievement of the project, that has recently made its halfway point, are presented divided by area of activities, namely:

- Benchmarking: assessing the freight system on selected routes and throughout Europe;
- Duty requirements for the freight-track system;
- Freight vehicle;
- Infrastructure;
- Business case;
- Technology demonstration.

Project activities and achieved results

Benchmarking: Assessing the freight system throughout Europe

Three routes have been selected within SUSTRAIL to assess the freight system performance. The routes are presented below, together with their main characteristics.

- Spanish Route. The route is part of the Mediterranean Corridor that has the potential to increase capacity, as current freight volumes are significantly low. Rail freight in Spain holds only 5% of the land freight market. Increasing the average freight speed from 75 km/h to 100 km/h along the route (passenger traffic on this route currently has an average speed of 100 km/h) would increase capacity.
- Bulgarian Route. The route runs between Kalotina, at the Serbian border, to Svilengrad, at the Turkish border. Rail freight holds a 10% share of total goods carried by surface transport in Bulgaria. The average train length along this route is 500 m, suggesting capacity may be increased by increasing the number of wagons per train. Increasing the average speed of freight along this route from 75 km/h to 120 km/h (potentially 140 km/h) would also lead to an increase in capacity. There is potential to increase speed up to 120 km/h on this route.
- UK Routes. Two routes have been selected: the Cross Country route, running west from Felixstowe and the route from Southampton heading north towards Birmingham via Reading. Rail freight holds an 11% share of surface transport in the UK. An increase in freight market share could be achieved through improvements to the loading gauge. Freight runs at up to 120 km/h, but on other sections freight runs at well below its potential speed (often around 50 km/h) due to going into loops or slow lines and because of being stopped for passenger services.

A number of general observations can be made on the infrastructure. There is a clear need to upgrade old infrastructure and move from single to double track. In this case, renewal costs would be high, but subsequent maintenance costs should be significantly lower. The increase in system capacity and removal of speed restrictions are additional benefits. Track geometry and track components are a major source of faults, particularly in switches and crossings, tight curves and steep gradients, and there is scope to improve the materials, designs and monitoring and inspection technologies.

Given the benchmarking provided on selected routes, SUSTRAIL moved ahead by looking at what "duty requirements" should be defined for upgrading existing freight railway systems, having an impact on both vehicles and infrastructures.

Duty Requirements

Duty requirements have been identified for current and future freight traffic flows and track design requirements for reduced maintenance activity and whole life cost. Detailed requirements have been provided across the following specific areas:

- Interoperability
- Logistics
- Track design, including specification of track performance, climate conditions and traffic loading
- Future train performance, considering the impact of vehicle speed, unsprung mass and axle loads
- Vehicle-Track System, defining the base case for current vehicle-track system and supports judgement on future systems

In this framework, a number of simulations were undertaken to determine the effects of speed, axle load and suspension design on both track and vehicle damage. The results provided a prioritisation methodology that takes into account both qualitative and quantitative effects of changes to the track-train system. Identified priorities were ranked in terms of their priority levels from low to high with the implication that: High priority items will be pursued most urgently; Medium and Low priority items will be given less priority. However even the Low priority items are important – Low priority reflects greater risks and/or smaller apparent rewards. The following table lists them and identifies to what part of the system (e.g., vehicle or track) they belong.

Figure 1: Rail Squats as a form of Rolling Contact Fatigue

Table 1: Summary of Duty Requirements

Priority Level	Duty Requirements for Improvement	System
High	1. Modest increase in freight speed (e.g. 120-140kph UK; 100-120kph ES,BG)	whole
	3. Optimise axle load limits (22.5t / 25t / 17-20t)	whole
	7. (20%) reduction in energy used by rail vehicles	vehicle
	12. Requirement for Vehicle Green Label for sustainability performance	vehicle
Medium	5. Reduce vertical ride force (RFCC) by 60%	whole
	2. Uniform vertical stiffness (track) - optimise between 50-100 kN/mm	track
	8. (20%) reduction in unsprung mass of freight vehicle	vehicle
	9. Optimise (/potentially double) service life of track components	track
	10. Combine components that have a similar service life (harmonise MTBF)	track
	6. Reduced rate of tolerable defects	track
	4. More reliable insulated rail joints (life*5)	track
Low	11. Independent power supply for braking & refrigeration	vehicle

The freight vehicle of the future

The work carried out in SUSTRAIL with reference to the vehicle aims mainly to come up with solutions for freight vehicle innovation at two different levels:

- An "improved conventional" vehicle using optimised existing technology and a demonstrator for this is being built as part of the project.
- A study for a "futuristic' design" of a sustainable freight bogie utilising technology which has not yet been proven in the railway field but has great potential.

In both configurations (e.g. conventional and futuristic), investigations have been made on new wheel profiles and improvements in suspension design responding to the needs of a mixed traffic railway; traction and braking systems for high-speed, low-impact freight operation; novel materials for lightweight, high-performance freight wagons; and advanced condition-based predictive maintenance tools for critical components of both railway vehicles and the track. Within this scenario, the technology improvements are based on the conventional and widely used Y-series bogie, and all design and performance calculations are compared to a reference benchmarked vehicle of a Y25 flatbed container wagon. The impact of these technologies on running behaviour, safety and track forces are being investigated using multibody railway vehicle dynamics software.

Figure 3: A "Y series" bogie with double Lenoir links

Figure 2: Diagram showing multibody railway vehicle dynamics

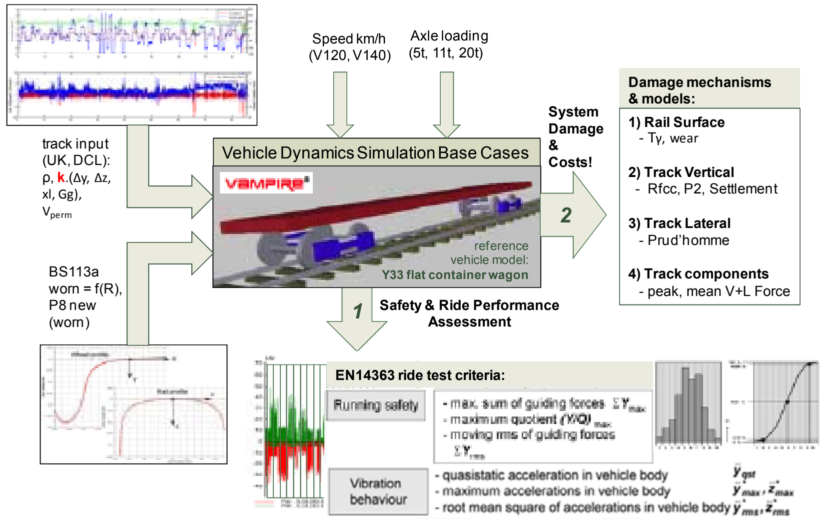


Figure 4: The radial arm as used in the Infra-radial project

Sustainable track

Building upon the duty requirements, optimising track design and maintenance approaches to move towards the 'zero maintenance requirement' ideal is a further issue SUSTRAIL is working on. Increasing track component life, improving condition assessment/monitoring and reducing maintenance activity will all play a part in increasing capacity and speed whilst reducing costs, thus contributing towards making rail freight more competitive and sustainable. Track failures have been identified and ranked by means of a Failure Mode and Effect Analysis (FMEA) to determine where to focus activities. This has been undertaken with the project Infrastructure Managers to ensure issues specific to their unique operating environments have been included in the analysis. The outputs from the FMEA have resulted in a number of solutions being considered for further investigation and will also support whole life analysis by the business cases.

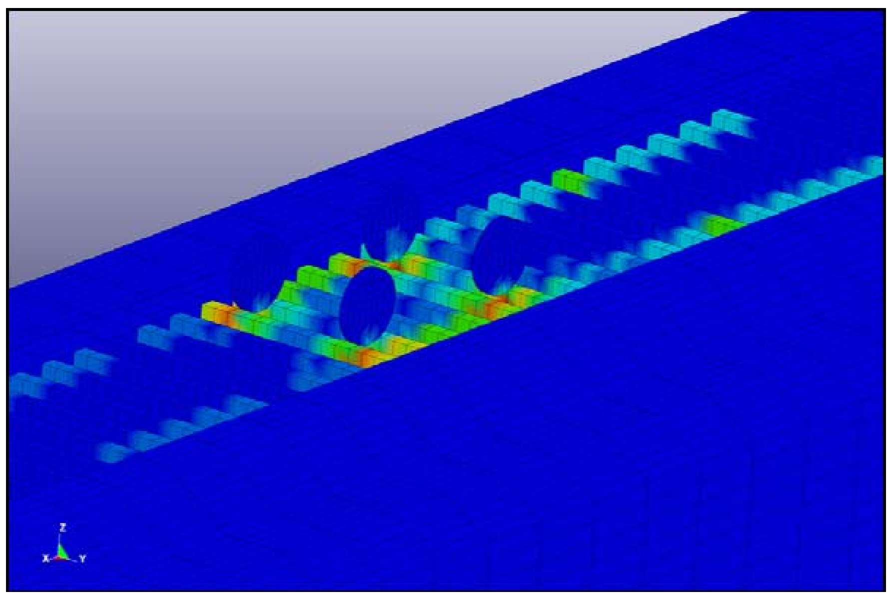
The FMEA was carried out with the aim of moving from deterministic to probabilistic (e.g. performance-based) approaches. This means that random variables defined by means of statistical distribution combined in stochastic process are being considered in the design of the track aimed at carrying out a full reliability-based analysis; the FMEA constitutes the initial steps. Furthermore the adoption of performance-based design methods accounts for the behaviour of a component/system across a certain time frame (life cycle) that is fundamental in terms of maintenance tasks. Indeed, estimating the changes of a component/system across its lifetime allows the adoption of condition-based and predictive maintenance approaches whose aim is to minimise the need for unscheduled operations, thus lowering the number and impact of maintenance tasks. Moreover, a performance-based design approach allows the investigations of track upgrades that SUSTRAIL is proposing, since they can be proven in a life-cycle perspective.

Figure 5: Example of failure mode identified by the FMEA

The importance of this approach is much clearer if one considers that of maintenance and renewal costs of a typical railway, track and substructure represents 50 – 60 % of the total cost.

With this in mind, it is quite clear that track and substructure upgrades are fundamental to achieve a significant impact on the overall cost reduction for the railways. To give an example, new solutions for subgrade improvements are being studied in the project, such as the use of piling using inclined columns, use of different rail steel grades, as well as use of geo-textiles, innovative track forms, and solutions for reducing the maintenance and renewal costs of track. They are being investigated through numerical simulations of wheel-rail interaction to quantify the benefits in terms of increased performance over the life-cycle of a typical railway, thus reducing the total cost of track and substructure.

Figure 6: Modelling track-wheel interaction and substructure conditions



The SUSTRAIL Business Case

Building upon the prioritisation of duty requirements, and the identification of innovations and upgrades identified in both freight vehicles and infrastructure, business cases are being implemented aiming at providing, on a qualitative and economical basis, the potential costs and benefits for end users of the proposed SUSTRAIL innovations. Recommendations for whole-system implementation, including phasing-in of novel technologies and strategies for the equitable redistribution of whole-system savings will also be provided. The business case will be finalised towards the end of the project (May 2015); however, six main scenarios have already been identified as shown in table 2.

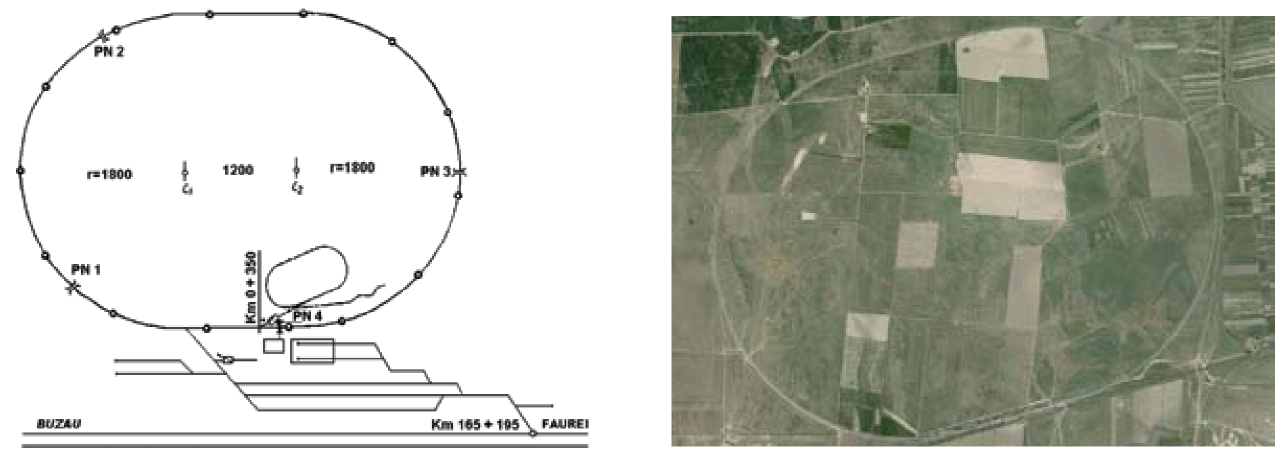
For the purpose of developing the analysis tools, a set of starting assumptions was made about the impacts of the SUSTRAIL vehicle innovations, including: a 5 % reduction in track access charges following a reduction in dynamic forces and in track damage; a 10 % improvement in reliability measured by train delay per tonne-km; a 7.5 % reduction in journey-time-related costs; a 20 % reduction in fuel cost for a given load; a reduction in wagon maintenance and non-fuel operating costs of 10 %; and a reduction in emissions factors for rail by 20 % matching the reduction in fuel consumption. A key element of the business case is the assessment of Technical Implementation and Phasing. A literature review is being prepared which addresses the state of the art in relation to human factors issues and operational issues arising from the integration of novel vehicles and track systems into the existing railway. The expected outputs in this sense will include:

- the projected time profile for introduction of the new vehicle into the European fleet over the period from 2015 onwards;
- the projected time profile for introduction of the track innovations on the European mixed-traffic network from 2015 onwards.

Table 2 : Business case scenarios

Scenarios	Baseline vehicle	Improved 'Conventional' Vehicle	Futuristic Vehicle
Baseline Track	i	ii	iii
Improved Track	iv	v	vi

Figure 7: The AFER's Făurei Test Centre: line diagram (left); aerial view (right)



Technology Demonstration

SUSTRAIL upgrades and innovations will be tested and demonstrated in full-scale tests in Romania at the Făurei test centre operated by the Romanian Railway Authority (AFER). The testing centre, established in 1978, consists of:

- A large ring featuring the following characteristics:
  - o 13.7 km with 6 footbridges and 4 level crossings;
  - o maximum speed of 200 km/h;
  - o electrification in single – phase alternating current of 25 kV/50 Hz with the level of catenary at 5,5 m;
- A small ring featuring the following characteristics:
  - o 2.2 km with 5 footbridges;
  - o maximum speed 60 km/h;

Initial telemetry tests have been carried out to set a benchmark against which the SUSTRAIL innovations can be compared. A reference test vehicle was used (an EAOS Ordinary open high-sided wagon, UIC 571-2) and the following tests carried out: braking system testing, noise level measurements, wheel profile measurements, track measurements including track and rail profile measurements. The same testing will be carried out on the SUSTRAIL vehicles and on the SUSTRAIL upgraded track.

Conclusions and Outlook

The SUSTRAIL FP7 research project (www.sustrail.eu) "The sustainable freight railway: Designing the freight vehicle-track system for higher delivered tonnage with improved availability at reduced cost" aims to improve the performance of freight rail. SUSTRAIL will implement a combined approach to innovation in rolling stock by developing advanced vehicle component and subcomponent concepts using innovative materials and production processes. Reliability-based design will be employed aiming at reducing uncertainties, optimising maintenance activities and thus reducing life-cycle costs of a typical railway system. Finally, SUSTRAIL aims to deliver the ideal combination of novel freight vehicle design coupled with novel sustainable track concepts with respect to the project core pillars of sustainability, competitiveness, and availability. ■

Sustrail: Устойчивое "Грузовой автомобиль-рельсового пути" системы

Устойчивого и эффективного грузового транспорта в Европе играет жизненно важную роль в том, успешной и конкурентоспособной экономики. Грузовые перевозки как ожидается, вырастет примерно на 50 % (в тонно-километрах) к 2020 году , когда больше грузов и более пассажиров будет путешествовать по железной дороге , для удовлетворения краткосрочных , Европы средних и долгосрочных потребностей трафика. В связи с этим , железнодорожный транспорт является уникальным по своей сложности . Это единственный сектор транспорта, которые должны рассмотреть автомобиль ,транспортная среда (например, трек) , и сеть (потоки , положений, процедур) параллельно. Железнодорожный транспорт также является уникальным во всем многообразии операционных процедур, норм, правил , руководящих принципов и бизнес-моделей по -членах ЕС. Изменения для железнодорожной отрасли является необходимым и конъюнктурными. В рамках этого проекта ЕС SUSTRAIL был запущен в июне 2011 года , направленный на содействие новой эры в секторе железнодорожных грузовых перевозок принятие всеобъемлющего подхода , внедрение четкой методологии и жизнеспособные процедуры для комбинированной улучшение в обеих грузовых транспортных средств и отслеживать компоненты . ■