INNOTRACK - Innovative Track System - A Unique Approach of Infrastructure Managers and Competitive Track Supply Industry for Developing the Innovative Products of the Future

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INNOTRACK is a R&D project that started in September 2006 and has gathered 35 European participants to a joint project. Among the rail infrastructure managers (IM) are several leading organizations. Also among the industrial partners several of the leading suppliers are participating. It has given a unique opportunity to bring together rail IMs and industry suppliers, the two major players in the rail industry, and to concentrate on the research issues that will contribute to the reduction of rail infrastructure Life Cycle Cost (LCC). Also several of the leading European universities in the area are actively participating. INNOTRACK is a comprehensive project with objectives from the EC White paper on Sustainable Transport. These objectives are increased traffic, reduced LCC and increased market shares on the freight and passenger market.

To achieve these objectives, investment alone is not sufficient, significant innovation and technology transfer is essential. This can only be achieved with very close cooperation between IMs and industry suppliers. It is essential that the IMs, as end users, set out their priorities and needs, at a European Level, to solve the necessary problems for achieving the white paper objectives. To ensure that cost reductions can be consistently evaluated across Europe, INNOTRACK will also devise an innovative generic methodology for LCC calculation, based on best LCC practices at EU level, to be used by IMs across Europe. Logistics for track maintenance and renewal is also included. This will be done by performing research on three key topics:

- Track support structure
- Switches and Crossings
- Rails and Welding

The innovation process flow, from problem identification to the verification of technical and economical solutions, is demonstrated, together with the SP responsible for each development stage.

One of the greatest problems encountered by railways in Europe is that track costs, the major cost component for IMs, have not significantly decreased in the last 30 years. In the same period of time, competing modes of transportation have seen a significant reduction of LCC. This narrows the business case for rail transportation. In addition to costs, noise pollution also became a crucial issue for railway operations. Both issues can only be tackled by increasing focused R&D and standardization at European level. This expected railway market share growth requires improvement of the current levels of reliability, availability of products and services framed by a market-oriented railway system approach.

The Railway Vehicle Industry has responded to the new challenges set before it, and will continue to respond by implementing:

- Increased speed and acceleration
- Increased axle loads and traction power
- More rigid vehicles with greater stiffness

These innovations however have a downside: they place greater demands on the track, causing more damage and higher maintenance costs. INNOTRACK main objective is to reduce the LCC, while improving the RAMS characteristics (Reliability, Availability, Maintainability and Safety) of a conventional line with a mixed traffic duty.

Railways also endure various other problems. They have suffered for too long from innovative technologies that turn out to be too ambitious and expensive to maintain.
At the World Congress in Edinburgh of Rail Research, it was claimed that two-thirds of all railway research is undertaken by the supply industry and this leads to significant innovation in products and services offered by the industry. However, the time to market and acceptance by IMs needs to be significantly reduced to justify the continued investment in R&D by the supply industry. To decrease time to market while reducing LCC, a European approach is required to support economy of scales and standardization of railway infrastructures.

INNOTRACK will also implement appropriate changes to specifications and standards to achieve reduced LCC, time to market and cost of safety.

As an overall measurable objective, through the innovations and changes provided by INNOTRACK, the IMs are expecting from INNOTRACK a 30% LCC reduction of track-related costs. This objective should be considered in relation to the fact that track related costs is more than 50% of the maintenance costs.

INNOTRACK will provide railway infrastructure managers with crucial information and technologies to facilitate the understanding and implementation of leading edge track system technologies, which can effectively contribute to LCC optimization for:

- Track support structure
- Switches and crossings
- Rails and welding
- Logistics for track maintenance and renewal
- Furthermore, decision-making algorithms will be developed in order to harmonize the LCC calculation and provide comparison points on a European wide basis.

The INNOTRACK project is a joint response of the major stakeholders in the rail sector – IMs and the railway supply industry – for the development of cost effective high performance track infrastructure, aiming at providing innovative solutions towards significant reduction of both investments and maintenance of infrastructure costs. This is needed:

- To develop the necessary leading edge track system technologies in the shortest possible timescales and ensure full market acceptance by IMs
- To speed up the realization of the highly efficient Trans-European network so as to accommodate the increased passenger and freight traffic by 2020 as envisaged in EC White Paper

To achieve these objectives investment alone, even if achieved to the desired level by EC (220 billion for 30 TEN projects and 600 billion for all TEN projects), is not sufficient. A radical step change of the efficiency of rail systems including significant innovation and technology transfer is essential.

The paper presents the INNOTRACK project from an overall view and some examples on results that have been delivered in January 2008.

The structure and basic idea of INNOTRACK

The main research activities of INNOTRACK are performed in sub-projects (SPs) SP1 to SP6.

SP1 has guidance and supporting role. The key deliverables from SP1 are the following:

- A methodology of track and vehicle categorisation and a generic model capable of predicting failure and degradation rates for a range of track, vehicle and traffic parameters. These models will be used for design, LCC and evaluation of new products.
- An identification (from information provided by Infrastructure Managers and supply industry companies) of selected segments of plain line tracks and...
switches and crossings locations where the duty conditions are sufficiently onerous to cause rapid deterioration which leads to a high frequency of maintenance or renewal. These sites will provide the conditions for evaluating the benefits of innovative products and maintenance practices being developed within the other sub-projects.

SP6s objectives are to:
- define and implement life cycle costing (LCC) and reliability, availability maintainability and safety technology (RAMS) for the infrastructure in an international framework.
- develop a relational database and verified solutions in close collaboration with SP 1 and participating IMs.
- analyse LCC as a service function for sub-projects 2 to 5.
- verify technical and economic solutions.

Figure 1: INNOTRACK’s SP structure

SP5s objectives are logistics and especially the optimisation of the supply chain. This will be the focus of SP5. In particular the ease of installation, quality, cultural and management issues will be assessed. One objective is to get people, materials and plant to site in a cost effective, simple and efficient way. This may be broken down to the following items:
- Establishing best practices,
- Developing innovative cost-effective and high-performing new construction techniques.

New cost-effective and high-performing transport, unloading, and renewal techniques in particular, will be studied in details. Examples are to assess the:
- Benefits of selected solutions such as just-in-time delivery of rails and other track components to the construction site in order to decrease the size of storage area
- Benefits of pre-assembled plug & play turnout solutions to make S&C easier to install
- Logistics costs by considering usage of combinations of available rail lengths and strategically located welding plants as well as mobile welding machines
• Implications to LCC of the use of long rails

In figure 1 you can see the structure of INNOTRACK.

SP2, SP3 and SP4 are more traditional projects dealing with different technical areas. They are liked together with SP1, SP6 and SP5.

SP0 is Management and coordination.

Finally SP7 is Dissemination and Training. The SP7 is vital for the overall project. Widespread dissemination and implementation of the project results assures sector acceptance and implementation of these results.

This subproject is organised and managed to assure awareness and implementation of results to all stakeholders inside and outside the consortium and liaise with the IP for light rail. Implementation of results is the ultimate goal.

INNOTRACK has also a special focus on implementation. Several of the deliverables will be made as guidelines so that they easier can be implemented by the IMs.

To assure high quality of the deliverables and also that the result have strong support among the end-users there is an extensive review process in INNOTRACK.

The project consist of three Work packages, namely

• WP7.1 – Dissemination and Standardisation Platform
• WP7.2 – Training Platform
• WP7.3 – Technical Review

SP7 is lead by UIC and UNIFE.

**SP1 Duty**

The work of SP1 is focusing on defining the root causes of degradation for the critical problems encountered by participating IMs. The result is to provide a verification that proposed solutions are valid in a whole system context and for the range of present and future traffic to be encountered across Europe.

Some examples from SP1 that will be presented are:

• Vehicle Characteristics from a large number of European countries.
• Track Characteristics from classified track segments
• The result of workshops defining cost drivers.

An example from SP1 today is deliverable D1.1.2 database of European Generic Vehicle Characteristics.

Infrastructure Managers have traditionally been cautious regarding the introduction of new technology into the railway system, as unproven innovation may introduce unexpected and serious risks. Product acceptance procedures may further inhibit or prevent the adoption of new ideas as the benefits may be considered insufficient to justify the risks. The result of this caution is that some regard the railway as unreceptive to new ideas, and lagging behind other transport modes. INNOTRACK should correct this view as the IMs seek to reduce whole life costs by the introduction of new technology. However the need to ensure that the innovative solutions resolve the issues and do not import new problems to the railway remains.

SP1 seeks to address this need within INNOTRACK by modelling the vehicle track interaction for the problem conditions identified by the IMs to ensure that the root
cause of the problem is fully understood and that the solution proposed successfully addresses this cause without introducing new risks.

The simulations must ensure that solutions are suitable for a wide range of present and future traffic conditions across Europe, focusing particularly on mixed traffic railways. Such a study has not previously been carried out on a European level.

The function of SP1 was to gather the vehicle characteristic information to enable INNOTRACK to ensure that most technical solutions are suitable for the wide range of vehicle characteristics possible in Europe not only now but also in the future.

As a first step deliverable D1.1.1, “Database of representative vehicle types and characteristics from participant countries”, identified the representative vehicles and their characteristics for the European partners. A database of summary vehicle data was developed to enable the selection of representative European vehicles which would form the basis for generic vehicle models.

Although the amount of detailed vehicle information provided was limited a range of vehicle dynamics models representing a number of European vehicles was brought forward.

This paper proposes that for each of seven European vehicle types, three models will be produced representing a low impact vehicle, a high impact vehicle and what may be considered as close to a typical vehicle.

A generic model has been developed for the Multiple Unit case which can be used for the basis of the three Multiple Unit generic models. Although the database includes some wheel and rail profiles, there continues to be an urgent need for partners to provide libraries of profiles for moderately worn and fully worn wheels and rails under a range of operational conditions. This is important as the forces generated by new wheels on new track are frequently very different to the interaction of worn profiles and it is essential to ensure that the range of conditions and load spectra that track is subjected to can be accurately characterised when verifying the solutions developed by the INNOTRACK project.

SP2 Track Support Structure

The primary objectives of SP2 are to identify means of achieving a 30% reduction in LCC within the rail–track structure. This will be achieved by providing innovative tools and methodologies that will support;

- Distinct decisions (based on LCC and duty recommendations), whether construction work is necessary and, if so, how much
- Low maintenance tracks (less activities, easier/automatic/self-inspection, diagnosis and monitoring)
- Changes in track-structure to provide better load distributions and/or higher load carrying capabilities
- Cheaper materials (e.g. in new build formation)
- Cheaper construction (see also the Logistics SP)
- Shorter construction time
- Reduced renewal possession
- Maintenance with minimal traffic interruptions

An example from SP2 is stiffness measuring carried out by the RSMV. You can see a picture of the car and also the principle.

Stiffness measurements have been available in a couple of research projects during the last couple of years. It has however been hard to find generally applicable explanations to track maintenance problem sites by the stiffness parameter alone. Therefore, in the INNOTRACK project a combination of parameters (mainly track
geometry, ground penetrating radar and stiffness) will be studied with advanced statistical methods in order to find patterns in the measurement parameters that can classify which type of problem there is and also the root cause of that problem. During this process a couple of tracks will be in depth investigated in order to train the statistical methods. The desired outcome of this research will give the maintenance engineer the possibility to choose the correct maintenance measure from a root-cause perspective and also to judge the problem from an LCC-viewpoint.

Figure 2. A picture of the RSMV Rolling Stiffness Measurement Vehicle and the principle

SP3 Switches and crossings

The field of switches and crossings is a key issue for the development of railways. On one hand switches and crossings provide flexibility in train operations, on the other hand, they are weak points in the system and overly represented in failure and damage statistics.

Within INNOTRACK there are efforts to analyze and optimize key parts. This work includes data mining, theoretical analyses, physical testing and implementation of demonstrators.

As an example of knowledge already derived within the INNOTRACK project, work presented in the PhD-thesis of Elias Kassa can be taken. This work featured numerical simulations of train–track interaction accounting for high-frequency load components. These simulations were validated and calibrated towards in-field measurements and low-frequency simulations.

It was found that for lateral vibrations, the influence of the high-frequency content of the load was slight. For vertical train–track interaction on the other hand, the load contribution in the frequency range 20–200 Hz is some 40% of the contribution in the range 0–20 Hz, see figure 3. This is a result of high interest to the INNOTRACK project’s efforts in switch optimization.
Figure 3. Maximum measured lateral and vertical wheel–rail contact forces in the crossing panel after low-pass filtering with different cut-off frequencies.

Another example of the work on switches and crossings carried out already in INNOTRACK is the work on deriving a common European guide for functional requirements for hollow sleepers for UIC 60 switches.

This specification is based on the requirements of the European railway operators to applications of integral switch and monitoring system. This specification will be declared a European standard.

In specifying the geometrical requirements maximum importance was attached to small dimensions (compact components) so that especially for the switch setting systems no restrictions shall apply with regard to mounting, layout and transport. Nevertheless the mounting space should be determined in such a way that the majority solutions for setting system components can be integrated into the hollow sleepers without difficulty.

The specification covers in detail:
- Geometric specifications for the hollow sleeper
- Functional requirements
- Requirements in terms of availability and reliability
- Description of tests required

SP4 Rails and Welding

The rail with welding provides the interface with the vehicle system and transfers imposed loads into the track system. In a systems context, the life expectancy of a rail is influenced by its interactions with the other parts of the train-track system. The faster and more frequent train services, higher axle loads and new generations of vehicles with greater primary yaw stiffness have significantly increased the critical track forces leading to rail-damage and the need for more frequent and costly maintenance intervention and even rail renewal.

The objectives of SP4 are.
- To establish causes and consequences of rail and joint degradation. To recommend alternative procedures without prejudice to the costs and the geometrical quality
- To establish definitive guidelines for the selection of rail steel grades and joint designs
- To establish laboratory tests that may validate operational findings and extract material characteristics of relevance to rail and joint degradation
- To provide data for development of in-service standards for joint and rail geometries
- To establish innovative minimum action rules, inspection procedures and maintenance strategies
A key issue curtailing the life of rails and increasing the cost of maintenance is rolling contact fatigue (RCF) caused by excessive stresses from the rail-wheel contact. This topic has been the centre of railway research in many European countries including previously EU funded projects.

An example from SP4 is deliverable D4.2.1 is squat development process. His has been postulated based on the correspondence between on the one side the calculated contact force magnitude and its wavelength and on the other side the field-observed squat dimension and the wave pattern following them. The wave length is between 20 – 40 mm. When the traffic speed is about 140km/h, which is typical on the Dutch railway, the frequency is about 1000 – 2000 Hz. It bears resemblance to short wave corrugation.

The postulated squats growth process is as follows:

**For a class A squat growing into class B:** As is shown in figure 6, with proper size, position, track and traffic conditions,

a. A typical squat A will have a first impact with a passing wheel at B₁ of (b) (i.e. B₁₀ of (a)), causing a peak contact force B₁ of (c). This peak force after many wheel passages turns point B₁ of (b) into B₂ of (d).

b. Then a second peak force C₁ of (c) follows. This peak force first causes the wave C₁ of (b) in the early stage of the squat-A-growing-into-B process, and then gradually turns wave C₁ into the large plastic deformation between B₂ and C₂. This is to say that in such a process the part of rail top surface between B₁ and C₁ deforms gradually into part of the squat (the part between B₂ and C₂). This is in agreement with many field observations, as is shown in figures 1 and 2.

c. In the process of turning wave pattern C₁ into part of the squat, there may be for certain period no wave pattern after (i.e. to the right of) C₁ and C₂, because the force peak D₁ is not yet large enough to make a new visible wave pattern.
Figure 6 How a class A squat grow into class B

Traffic travels from left to right.
(a) Geometry of typical squats A used for the FE model, one of such is shown in (b);
(b) A typical squat A with typical wave pattern after it due to dynamic contact force shown in (c);
(c) The calculated contact force caused by the geometry of (a). Notice that peak B₁ is a forced vibration, while peaks C₁ and D₁ are free vibration
(d) A typical squat B

The red numbers indicate the distances (mm) between the A, B and C points. Subscripts 1 and 2 designate the 2 squat geometries simulated in figures 6 and 7. Subscript G indicates that it is the points on the simulated geometry. Note that the squats in (b) and (d) are two different squats.
Notice the similarity between the wave patterns of (b) and (c), it is postulated that A₁ of (b) is A₂ of (d), while B₁ becomes B₂ and C₁ becomes C₂.

The monitoring conducted by ProRail and TU Delft will provide data for the validation of this postulation.

SP5 Logserv (logistics)

The capacity assessment of a railway network is a core function of the IMs. The more saturated the network, the more important and the more difficult the task of taking possession becomes. There is always a trade-off between meeting the demands of the market (passengers, shippers, forwarders) and the needs to maintain the infrastructure in a reliable and safe condition. As long as the railway was an
integrated company, owning the infrastructure and running trains on it, the capacity assessment was an internal process, mainly based on experience. Little, if any, importance was given to the cost efficiency of capacity assessment. European railways reforms, with the introduction of competition and the split of operations from infrastructure management, have introduced new elements to the process of capacity assessment:

In a competitive environment and with limited public funding, the IM is significantly more market orientated on capacity management. The goal is to market as many train slots as possible in order to maximise revenues. With regard to the slots sold the IM is bound by contracts that generally include penalties for late or missed provision of infrastructure availability.

The objectives of SP5 have been written earlier.

In the deliverable D5.1.4 a report on interfaces between contractors has been presented. The outcome of interviews with some contractors is as follows. The interviews have been conducted by EFRTC using subcontractor. The following approach was taken for interviews:

- in the first stage the selected companies for interviews have been asked to respond to the structured web-site questionnaire agreed by SP5 members and managed by University Birmingham
- in the second stage they have received additional questions focused on quantitative evaluation of their interface to Infrastructure Managers as a further preparation for interviews
- finally the interviews have been conducted by EFRTC consultant (and SP5 team dedicated for interviews in the future).

The reports from interviews present valuable initial input to WP 5.1 deliverables outlining the ways for improvements and potential for costs reduction. The major findings are presented in the conclusion of the report.

The findings will be analysed and processed in the final report making the proposals for the overall improvement for interface between Infrastructure Managers and Contractors aiming at significant further cost reduction.

The preliminary findings from the first series of interviews are summarised as follows:

- European market opening in its infancy, needs decisive push
- Technical standards also an important area for real harmonisation
- Rules and regulations, particularly in safety and logistics (worksite protection and material supply) with a massive impact on productivity
- Contracting strategies of infrastructure managers vital for efficiency, e.g. long term planning, dependability, economies of scope and scale, output orientation (innovation, LCC-aspects), terms of employment/build-up and continuity of skills
- Track possession policy a hot and "efficiency-critical" issue (re-orientation necessary, vast potential for process-innovation to make better use of windows
- Industrial engineering of processes and worksites to be a prime area of management attention (good-practice knowledge management), concept of a "mobile factory"
- Fleet utilisation for heavy plant often for too low; high capital cost and immediate consequence; fleet size often far above real needs
- Key heavy equipment sourced from, oligopolies market, prices perceived to be excessive
- Design construct maintain contracts with potential for significant LCC-improvement
- "Price-only" procurement behaviour/rules hard to overcome, but economically disadvantageous
- Financial planning and budgeting cycles inappropriate for efficient work programming
- EIM input (2007), on "Cost Efficiency in Building and Maintaining the European Rail Transport Network" widely supported
- Cross-sectional learning throughout Europe an untapped source for optimisation

**SP6 Life Cycle Cost Assessment**

The objectives of SP6 are described earlier in the paper.

An example of result is D6.2.2 Benchmark of LCC Tools. Here it is stated that optimisation of track constructions or track components regarding technical and economic requirements is essential for railway companies to fit the market and to compete against other means of transport. Due to the long lifetime of the track and track components – ranging between 20 to 60 years – pre installation technical and economic assessments are necessary to optimize the track construction, and get the return on investment (ROI), in a manageable timeframe. LCC and RAMS technologies are two acknowledged methods for assisting this optimisation process.

The RAMS characteristics determine essential parameters of the system such as the usability and acceptability of the system, the operation and maintenance costs, and the users’ safety and health risk when operating the system. The RAMS technology is a recognised management and engineering discipline to guarantee the specified functionality of a product over its' complete life cycle, and to keep the operation, maintenance and disposal costs at a predefined accepted level, by establishing the relevant performance characteristics at the beginning of the procurement cycle and by monitoring and controlling their implementation throughout all project phases.

LCC is an appropriate method to identify cost drivers and to gather the costs of a system, module or component over its whole lifetime including development, investment maintenance and recycling costs. Different views and evaluations allow the comparison of different systems and delivers necessary information for technical and economical decisions.

In the field of railways, RAMS technology and LCC are as widely implemented as they could be and will provide a definite advantage to the IMs in helping calculate costs for the implementation of innovative technologies.

In the frame of INNOTRACK, these methods will be defined at a European level and used to identify cost drivers and assess the track components, modules or methods developed in SP2 to SP5 to fit the European problems defined in SP1.

What's new?

INNOTRACK provides a unique opportunity to deliver its contribution to these objectives by bringing together all major stakeholders – manufacturing and contractor supply industry, Infrastructure Managers, Railway Undertakings, System Integrators supported by European research excellence in order to concentrate on the research issues that will assist these ambitious objectives to be achieved.

The technology-driven research will focus on track support structure, switches and crossings, rails and welding, efficiency of logistics for renewal and maintenance, from the point of view of reducing LCC of track structures. INNOTRACK will propose, validate and implement the track design towards creating common European standards responding the demands for higher traffic volume, higher performance in terms of RAMS and LCC without compromising safety.
Author's Biography
Björn Paulsson today works for UIC in Paris leading this EU-project INNOTRACK. He has MCs in Civil Engineering from University of Lund 1974. He worked for Skanska, Sweden for 17 years very much focusing on civil engineering structures. In 1991 he joined Banverket, Sweden and has been head of Track and Civil Engineering Department at Banverket HQ until 2007.

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