The EU-project INNOTRACK – a description of highlights and how they have been implemented

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Abstract

The EC-funded project INNOTRACK focused on the development of cost-effective high performance track infrastructure, by providing innovative solutions that result in significant cost reductions of both investments and maintenance of infrastructure. Operative between September 2006 and December 2009 and covering a total turnover in the order of 25 M€, the project has delivered a multitude of results that are now being implemented in operation. The paper gives an overview of the project and where more information can be found; focuses on four “highlights” and discusses their character and how they are being implemented; and finally discusses some general issues regarding a successful realization and implementation process for such a large research and development project.

Introduction

The EC-funded integrated project INNOTRACK has brought together rail infrastructure managers, industry suppliers and research bodies in deriving innovative solutions to cut LCC (Life Cycle Cost) and improve RAMS (Reliability, Availability, Maintainability & Safety) of track structures. The project has had a turnover of about 25 milj € with 36 partners from 11 countries participating. The results are documented in some 140 deliverables and in accompanying material, the most important of which is the Concluding Technical Report [1]. INNOTRACK formally ended on 31st of December 2009, when the most challenging work started — the implementation of results. The current paper discusses how Europe-wide cost drivers and corresponding root causes were identified and met by innovative solutions. As more in-depth examples, four topics will be presented and it will be described how the derived solutions have been, and are being implemented in the railways.

Organisation of the INNOTRACK project and supporting subprojects

The project featured three “traditional” technical research and development (R&D) subprojects, focused on ground support structures, rails and welding, and switches and crossings, respectively. In addition, three supporting subprojects were formed to put the technical results in context, see Figure 1.

Figure 1 Organisation of INNOTRACK

The first such subproject dealt with an identification of the common European cost drivers and their pertinent root causes. Here, an important conclusion, derived from workshops at infra-managers around Europe and additional in-depth analyses, was that most of the important cost drivers are

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indeed common European issues. This confirmed the benefits of the common European approach in INNOTRACK. Further, it was found that the topics addressed within INNOTRACK addressed almost all top cost drivers. In addition, the subproject analysed the operational conditions in terms of identifying generic vehicles and track structures. The subproject also carried out a pilot study on technical assessment of an innovative product (in this case a slab track solution) from a systems perspective.

The second supporting subproject dealt with logistics. This topic was approached from a broad point of view that incorporated not only delivery to, and assembly in track, but also procedures regarding sourcing, regulations, (long-term) planning and budget processes.

The third supporting project evaluated the derived solutions from an LCC and RAMS perspective. This work set out with an evaluation of current LCC and RAMS practices around Europe. From this, a common LCC model was derived. This model clearly states which variables that are included and excluded from the LCC analysis, which makes the results very transparent and facilitates e.g. international comparisons. The developed model was then employed to estimate LCC benefits of the developed technical solutions. The analyses showed that for some innovations LCC evaluations are very cumbersome. These innovations basically fell in the areas of prevention of low risk–high impact incidents (e.g. rail breaks and subsequent derailments) and areas where legislative regulations are in place (e.g. the influence on corruption on noise and the resulting need for grinding). For the innovative solutions where LCC was evaluated, the calculations indicated significant LCC savings. The effect of the employed discount rate in the analyses should be noted. Basically, it can be shown that a too high (fictive) discount rate will effectively kill innovations. Thus, rail administrations should be very careful regarding their choice of calculation rates.

More details on the work in these supporting subprojects (and also the technical subprojects) can be found in [1] and the reports referenced therein.

**Technical subprojects – examples of “highlights” and their implementation**

Below, we will focus on four research topics in INNOTRACK. We will describe the innovative solutions; indicate their benefit and how they are currently being implemented.

**Four methods for subgrade improvements**

INNOTRACK has developed, implemented and evaluated four different methods for subgrade improvements: the use of geo-grids to improve the characteristics of a transition zone and the use of geo-composites (geo-grid and nonwoven geotextile) to improve the characteristics of a poor drainage zones have been assessed through full-scale testing. In addition, significant efforts have been devoted to laboratory testing and numerical simulations to characterize the effect of these reinforcement methods, [2].

Further, the use of vertical soil-cement columns, and inclined lime-cement columns have been tested in field. These methods exclude needs to close down the track during reinforcement actions, see Figure 2, which promotes significant cost savings and minimizes traffic disruptions. To validate the methods, excessive measurements campaigns and detailed evaluations of the mechanical characteristics of the installed columns have been carried out, [3].

To give an idea of the benefits of the innovative solutions, it can be noted that the mitigating actions at the transition zone allowed resumed operations at full speed (160 km/h as compared to the restricted speed of 10 km/h). Regarding the inclined piling, detailed LCC analyses are presented in [1]. These analyses showed significant cost savings even if the savings related to reduced (or eliminated) traffic disruptions were not accounted for.

The current status of implementation is that the INNOTRACK guideline regarding inclined piling has been implemented in Trafikverket's codes in Sweden. A workshop will be organized by the UIC during 2011 to device a coordinated strategy of implementing the geo-technology related innovations from INNOTRACK.
Guideline for rail grade selection

Based on a multitude of long-term track measurements, INNOTRACK has been able to develop and calibrate predictive models for wear and rolling contact fatigue [4]. These express, for a given rail grade, the wear rate and crack growth as a function of curve radius. From such a model, an optimum choice of rail grade can be obtained by balancing the decreased deterioration of premium grade steels to their higher cost. Through such an analysis, curve radius based criteria for rail grade selection has been developed [5]. Such criteria exist already as documented in the UIC leaflet 721 [5]. The work in INNOTRACK can thus be seen as a modernization of the current regulations based on an extensive set of modern operational data.

The criteria described above presume no further knowledge than the curve radius. This is a benefit when a new (or significantly upgraded) line is to be equipped with rails. However, in most cases there exists much more knowledge regarding the operational conditions, which can be employed in the rail grade selection. In particular the deterioration pattern on existing lines is usually known. For this reason also deterioration based rail grade selection criteria have been developed. Here, the input data is the current situation regarding rail grade, wear and rolling contact fatigue. The output is the suitable rail grade for the operational conditions at hand.

Regarding cost savings, an analysis for the Network Rail network [1] estimated LCC savings of the introduction of premium rail, rail grinding and lubrication to some 11% to 30% discounted over 40 years (27% to 54% at 2009/2010 prices).

The guideline on rail grade selection has now been employed by the UIC Track Expert Group and will form the basis for a revised UIC leaflet 721 or UIC/UNIFE TecRec. In addition, a provisional TecRec regarding grinding has been produced from the results derived in INNOTRACK.

Analysis of rail crack growth and fracture

The growth of rail cracks can be divided into two stages: a stage related to crack initiation and short crack growth and one phase related to the transverse growth of long cracks and the subsequent fracture. The former phase was the subject of work in INNOTRACK related to optimization of grinding practices and to establishment of innovative rail testing practices. A proper management of this stage of crack growth is strongly connected to the life cycle cost of rails. The subsequent stage is more related to safety assurance. However, prevention against rail breaks requires regular inspections with related costs. Further, means to prevent rail breaks may lead to traffic disruptions. This is especially the case when trains are stopped due to too high wheel forces. Such disruptions not only cause related costs, but also decrease the confidence in rail transports.

To increase the precision in rail inspections and alarm limits, a dedicated study in INNOTRACK focused on long crack growth and fracture. Two routes were followed. In the first, the load magnitudes, as well as the material strength of the rails were considered as stochastic quantities. Given an operational scenario, the risk of rail breaks could be evaluated as a function of time and inspection intervals established to ensure that an allowed risk magnitude is not exceeded.

The second approach dealt with deterministic evaluation of crack growth rates and risks of fracture. To this end, the influence of wheel flat and of hanging sleepers was given special consideration. A worst-case wheel flat load history and impact position was defined based on numerical optimisations
coupled with full-scale field measurements. The results quantified crack growth rates and risks of rail breaks under different operational conditions. In particular the detrimental effects of cold climate and hanging sleepers were quantified.

The work on rail crack growth and fracture was summarised in an INNOTRACK guideline [7] where detailed operational recommendations were given.

The analyses carried out in INNOTRACK and subsequent results are an important ingredient in the continuous revision of maintenance practices and regulations to mitigate winter related traffic disturbances. The analyses have been a key ingredient in the revision of alarm limits in Sweden, which was a pre-requisite for a wider use of wheel impact load detectors. On a European scale, the work in INNOTRACK will be merged with the results of a UIC study “Axle Load Checkpoints” to establish a common framework for wheel load measurements, alarm limits, and operational procedures.

**Optimization of switches and crossings**

Switches & crossings (S&C) are discontinuities in the track systems that impose high loads and are prone to mechanical failures. On the other hand, they are crucial in providing flexibility to train operations.

The aim of the studies in INNOTRACK was to optimize S&Cs with respect to imposed load magnitudes and pertinent material deterioration. To this end, several promising measures that included altered stiffness and geometry of the S&C were assessed [8]:

To decrease the stiffness transition imposed by an S&C passage, it is possible to optimize pad and ballast stiffness. The latter can be obtained through a modification of the ballast layer, or through the use of under sleeper pads and/or under ballast mats. To further increase the knowledge on the support stiffness distributions at S&Cs, a pilot study of full-scale measurements of loaded track stiffness along S&Cs was carried out using Trafikverket's Rolling Stiffness Measurement Vehicle (RSMV) wagon.

Regarding geometry, INNOTRACK has investigated the beneficial effect of dynamic gaugewidening on the steering of a train through the S&C. Numerical simulations indicate a strong potential for decreasing wear and RCF. Further detailed studies have been carried out regarding the influence of the stiffness and geometry of the crossing panel. Here, simulations showed how a combination of an innovative crossing design (MaKüDe) and reduced support stiffness at the crossing resulted in significantly reduced impact loads, and consequently a high potential for LCC savings.

Further, simulation techniques have been taken a step further in INNOTRACK through an innovative concept where multi-body dynamics simulations of switch negotiations have been coupled with detailed simulation of plastic deformation and wear of switch components, see Figure 3 [9]. To account for the spread in operational conditions, the simulations featured a variety of vehicle input data (worn wheel profiles, vehicle type, vehicle speed and wheel position at switch entry).

It should be noted that the numerical models have been verified and calibrated towards field tests. To fully quantify the benefits indicated by numerical simulations, full scale testing of S&Cs is in progress and planned to continue through 2011. Preliminary results indicate significantly improved performance of the innovative S&Cs.

![Figure 3 Flowchart for numerical simulation of S&C degradation. From [9].](image-url)
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The implementation stage

The INNOTRACK project formally ended December 31, 2009. The project resulted in some 140 deliverables (in the order of 10,000 pages of reports), a number of databases, and many innovative solutions. To make it possible for an outsider to get an overview of this massive amount of information there is a need for high-level overviews. Already in the early stages of the project some deliverables were designated as “Guidelines”. This implied that their aim was to summarize the results on a certain topic and focus on clear and stringent conclusions, recommendations and operational instructions. One example was a guideline on hollow sleepers [10] to house switch operation equipment that was employed as the starting point for a European standard within the CEN WG16 work group.

The guidelines provided an overview of a specific field. However, to also provide an overview of the entire project, a Concluding Technical Report was commissioned [1]. In drafting the Concluding Technical Report, an effort was made to identify all implementable results from INNOTRACK. The result was a list of 13 pages. Selected implementable results were then clustered into twenty “highlights” of which four have been discussed above. All of the “highlights” are described in the executive summary of the Concluding Technical Report and the list is forming the framework for Europe-wide implementation of INNOTRACK results.

To coordinate the implementation, an Implementation Group was formed from the INNOTRACK Steering Committee and Coordination Group. The group has identified implementation actions for all of the twenty “highlights”. It meets on a regular basis and tracks the progress in implementation towards the planned actions. Further, the UIC Track Expert Group will have an active role in supporting these actions with economical support for the implementation from UIC’s members.

In this context it is important to note that implementation is a process that is carried out on different levels, as outlined in Figure 4. The higher the level of implementation, the more widespread the implementation will be, but this also requires the implementation to be more general. Thus, thorough consideration should be made as to a suitable level of implementation. In Figure 4, tentative levels for implementation of the topics discussed in the current paper have been indicated. Note that several of the solutions require multiple implementation actions at different levels.

Concluding remarks

The four “highlights” presented in the paper are examples of innovative solutions developed in INNOTRACK. To gain acceptance for the proposed solutions, significant efforts have been put into quality assurance, validation and dissemination: All deliverables have been internally, and all major deliverables also externally reviewed by both railway and industry experts and external researchers. Further, as mentioned above, the work in INNOTRACK is now being extended by long-term assessment of the most promising solutions. Where possible, LCC gains of the derived solutions have been evaluated. If this proved not to be possible, an overview identification of benefits and drawbacks of the innovative solution has been made. Further, INNOTRACK has been presented in a wide variety of forums. In particular, half-day seminars have been held at most of the infra-manager and industrial partners. These have been very valuable in giving opportunities for focused discussions and outlining implementation strategies. INNOTRACK has also been presented outside Europe in Amman with additional planned UIC workshops in Tokyo and Dakar.
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From the experience in the seven years of preparing, realizing and implementing INNOTRACK, some crucial factors can be identified:

- It is important to involve end-users actively and early, but not before implementable results exist. In INNOTRACK this was mainly carried out through deliverable reviewing, which proved very positive both in providing good feedback and in spreading the knowledge.
- The role of the branch organizations (UIC, UNIFE, EFRTC, CER, EIM) is crucial since it provides a neutral forum through which implementation activities can be coordinated. In addition to this there is a need to structure the implementation in small portions so that each infra-manager focuses on a limited number of solutions, carries out this implementation within their organization or in smaller project groups and then shares the experience in the larger forum.
- The economy of innovative solutions will eventually be decisive for a successful implementation. It is therefore vital to determine and describe the benefits as detailed and objectively as possible. Here, the LCC evaluation tool developed in INNOTRACK is a significant step forward.
- The administration and overhead needs to be kept to a minimum. A European project in itself carries a significant administrative overhead. Efficient administrative and management routines are needed if this should not be overwhelming and crippling for the project. In particular it is crucial that the project management team has the mandate to take actions within reasonable time. In INNOTRACK this was handled by taking strategic decisions in a Steering Committee and handling practical issues in a Coordination Group, both of which met regularly. In general, this construction worked very well.

Finally it must be emphasized that a successful project must be built on a trust between the partners and an enthusiasm for the project. The long process of consolidating the consortium before the official project start had the benefit that it created such a trust and eventually led to that INNOTRACK is the largest European research project to date within its field where industry, infrastructure managers and research bodies have been cooperating on equal terms.

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