Building up on railway coordinates

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Key words
Track work, absolute railway coordinates, reference data, infrastructure work process, "railway project 2009", interoperability of railway infrastructure data at highest quality level based on absolute coordinates, expert feed-back.

Summary
The goal of the interdisciplinary, international meeting called "railway project 2009" was to outline the requirements needed to progress towards interoperable railway infrastructure data based on absolute coordinates along European Railway lines.

During the meeting, railway experts examined the requirements from three perspectives: Geodesy, GIS and the needs of the railway companies. In addition the interest of the track industry and the UIC were also considered.

This text starts by describing some of the fundamental components in the use of absolute coordinates in railways:

- The development for track work where absolute coordinate use was initiated (ch. 1);
- a rough overview of the reference data components (ch. 2);
- the potential of generalising the "work process approach" successfully implemented in the track domain to support the overall "infrastructure work process" (ch. 3).

The paper then focuses on the outcome of the "railway project 2009" meeting (ch 4) and the results of follow-up discussions (ch. 5), this by taking into account the statement given by the geodesy experts, that referencing the coordinate data to ETRS89 would allow the railway companies to move towards full data interoperability at a 1 cm-precision level.

Some personal feed-backs (ch. 6) clearly shows that the subject initiated by the "railway project 2009" is a potential starting point of an important ongoing work, to be dealt with by the railway companies, to enhance data interoperability. Ideally it might be accomplished by the interdisciplinary, international teamwork, involving the experts in direct interaction with the industry and with the railway management.

An outlook on the ongoing technical and organisational subjects to be deepened concludes (ch. 7) the work done.

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1 COORDINATES FOR TRACK MACHINE GUIDANCE[1]

Track data is the first domain of railway infrastructure data out of the general, absolute coordinate based geoinformation GIS management data set which reached highest level quality, allowing track positioning with mm-precision in relation to the reference points measured on the absolute, national coordinate reference system.

To meet that challenge, the data had to get a quality level of 100% CORRECT, COMPLETE and directly USABLE (Fig 1).

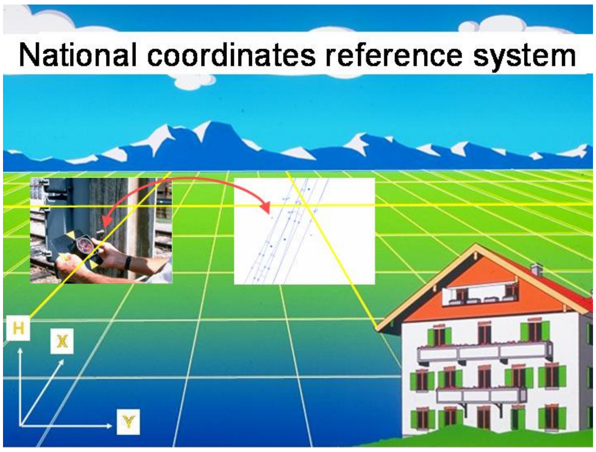

Fig 1: Coordinate based object referencing railway reference point

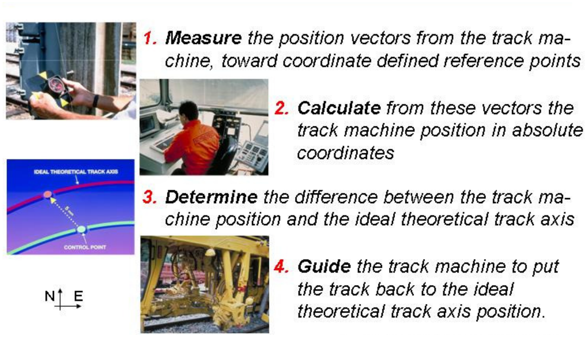

Fig 2: Coordinate based track machine guidance during the tamping work process

The fully automated 4 steps tamping work process steers the physical operations (Fig 2):

The track machine positions itself by measures (GPS or classical tachymetry) within the absolute coordinate reference system (1) and compares the determined terrain track position coordinates with the previously calculated, theoretic track position (2). This result delivers the lateral shift the terrain track position is to be corrected with mathematical precision (3) before tamping (4).

Following developments had to be accomplished:

- The change from relative working method to absolute coordinate reference track definitions as basement of the net wide, automated track maintenance work (Fig 3);
- The implementation of a systematic data management system including a fully automated data consistency and -completeness check before storing calculated track data on a central data base using the topological structure of the centrally stored track data[2];

[1] Today the absolute coordinate guidance is limited to tamping machine. In the future all types of machines will be absolute coordinate driven, i.e. in addition renewal trains and excavation machines.

[2] A topological structure of the track is composed of coordinate based nodes and edges. A node is a tip- or an end- point of a switch. An edge interconnects two nodes and is a geometric line, modelling the axis of the track

- The integration of all the functions developed on a hands-on, simply to handle track calculation system, fitted to the needs of the end user (track project calculators, track machines, …). At SBB the Toporail global track calculation systems is the successful answer to this challenge (Fig 4);
- Implementation of a work process driven approach (Fig 5).

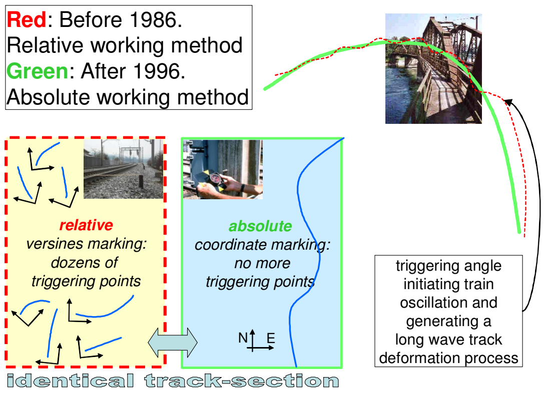

Fig 3. Relative versus Absolute track working methods

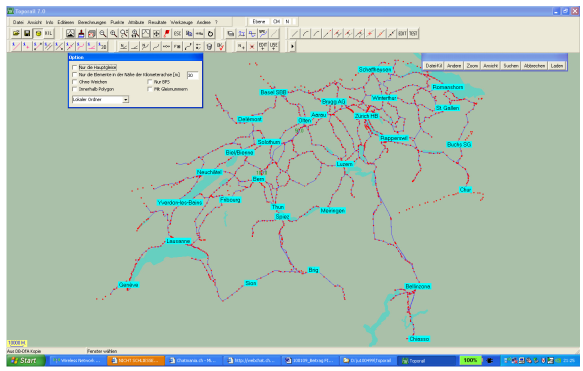

Fig 4: The Toporail track calculation system from the Swiss Rail

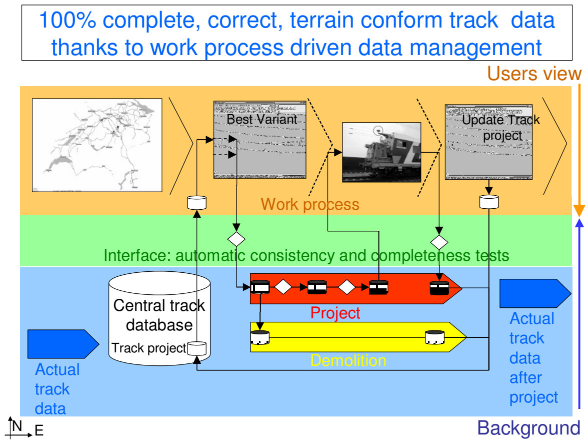

Fig 5: Largely automated, global track management system

Year	Total length [km]	Best track quality part [km]	Part of best quality [%]
Category 1 main track			
1996	2721.202	1080.428	39.7
1986	2579.004	509.229	19.7
The best track quality part comprises the track segments on which a note between 10-22 was measured by the track quality measuring car. The note is quoted on a scale between 10 for a perfect tracks and 110 for the worst possible track. The best track quality part doubled in 10 years.			

Fig 6: Variation of the track quality in 10 years tank to absolute coordinate

Today, all the track machines working on the SBB track net (> two dozen track machines each night spread all over the country) are currently supported by (nearly) complete and errorless track data.

on the terrain as a succession of straight lines and arc segments, which can be interconnected by clothoides. A topologically structured track net is complete and errorless thanks to the consistency checks which take place before the central data storage operation. Changing a switch means that all track lines ending on the respective node must also be recalculated. The track net consistency is controlled in the connecting points of the newly calculated existing track. The coordinates and the orientation must be identical for the existing track side as well as for the newly calculated (project) track side of the node.

Consequences were noticed at various levels:

- **Quality**: The track quality was doubled between the introduction of absolute track coordinates in 1986 and 1996 when the whole track net of SBB was entirely defined by absolute coordinates (Fig. 6).
- **Capacity**: In December 2004 SBB was able to increase the traffic by 14% when implementing its “Rail 2000 project”. The track quality increase was one of the pillars which made this project successful.
- **Organisation**: No track machine breakdown due to erroneous absolute coordinate based track data occurred since 1996.
- **Strategic importance of the organisational improvement:** As nearly half of the annual infrastructure maintenance budget is spent on tracks, the coordinate based data influence positively the maintenance cost.

2 REFERENCE DATA

The reference data allows an automatic, biunique reference of all specialised data of the railway infrastructure. They touch domains of:

- Reference point network,
- Route data,
- Work surfaces,
- Track data.

All these domains, being based on absolute coordinates, allow GIS-based graphic representations as showed in Fig 7.

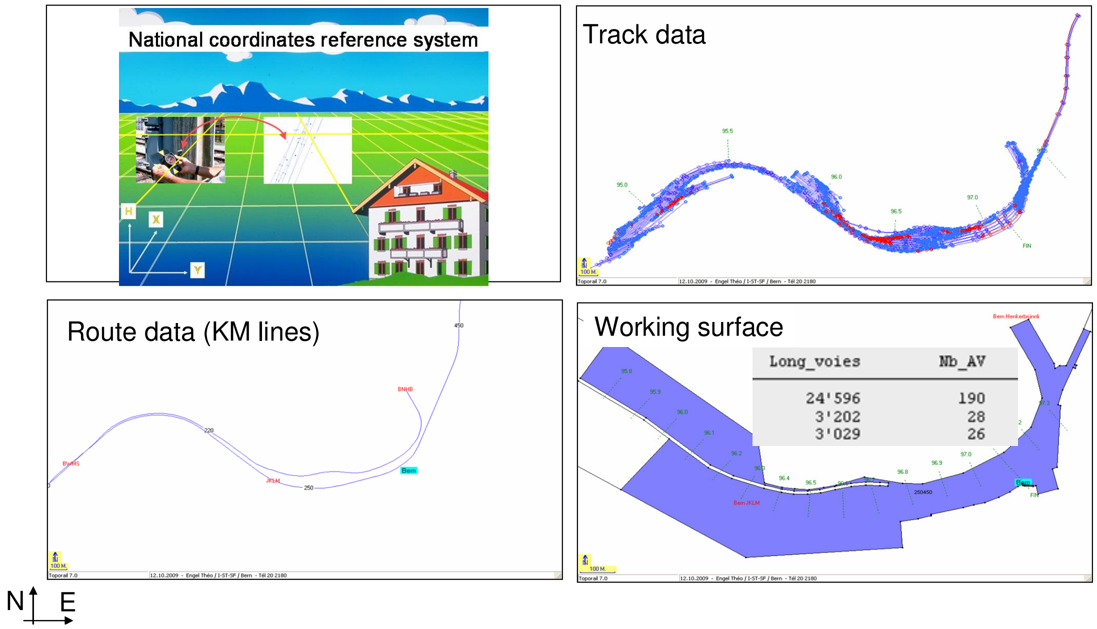

Fig 7: The four subjects addressed by the railway reference data

The relationship between the basic reference data, the track data and all the data of the specialised services can be shown by the coordinate based shell data model (Fig. 8) with:

- The route data and the work surfaces represented by the kernel.
- The track data as a first shell.
- All specialised services data, with varying completeness and correctness as a second shell.
- The railway map summarizing the content of all the inner shells as the outer shell.

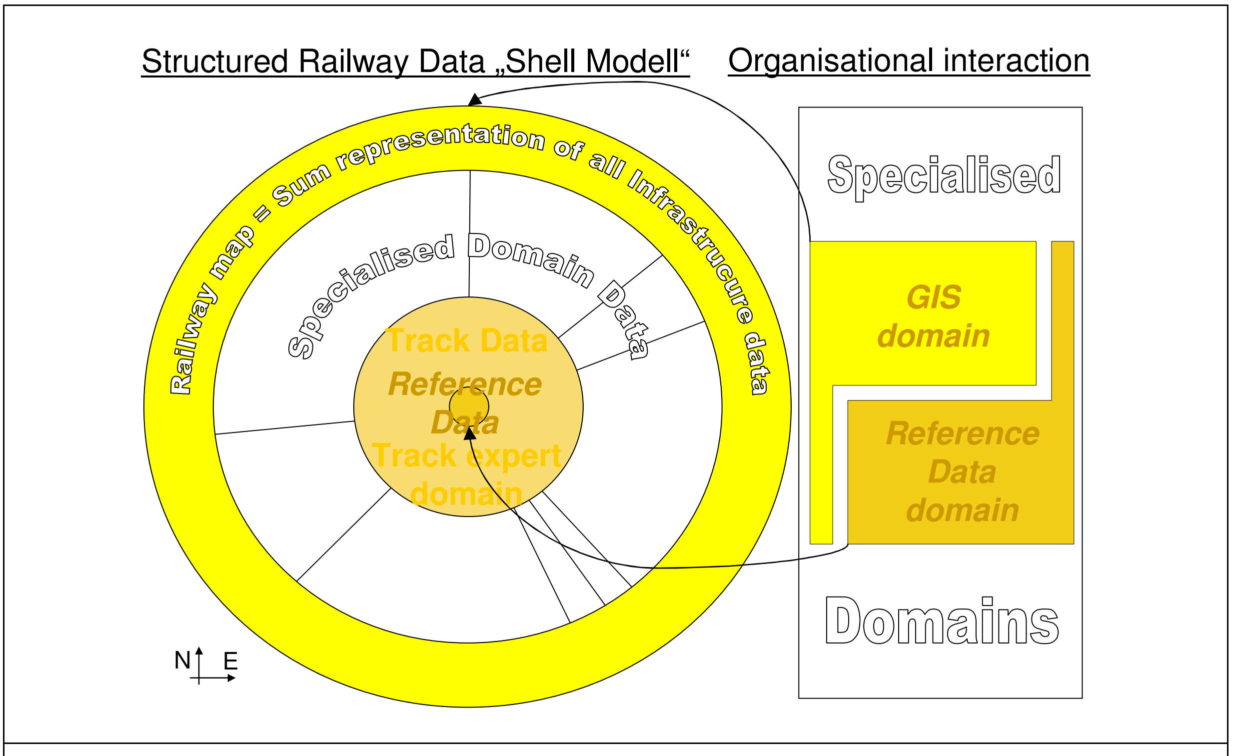

Fig 8. Shell data model and their organisational interaction

3 THE NEEDS TO EXPLOIT THE FULL COORDINATE POTENTIAL

After the development work achieved in the track domain with a fully structured data set supporting an integral work process approach, pioneering by doing so the aspect of highly reliable data management at maximum quality level, the opportunity is now open to extend this approach to the entire infrastructure work process with several additional data bases behind it.

To fulfil that vision, the full interoperability between ALL the different data bases is required.

A first step of interoperability can be reached by relating all the data (technical, finance, traffic, etc) to a unique, absolute coordinate reference. The precision of the position of the railway objects using either coordinates or route data, can be adapted to the user needs. This allows it to identify automatically the proximity of assets coming from different data bases by identifying their geographical attributes localised within a same work surface.

The final extension of interoperability based on full automatic data transfer between the infrastructure work process and the central data storage requires in addition:

- Topologically structured data according to the physical reality of the railway assets.

- A detailed information allowing to specify at what level interoperability is to be guaranteed: Shall it operate for comparing switches or distinct screws of a switch?

The fully integrated work process approach is therefore called „coordinate based, process driven, topology structured data management“ (Fig. 9). All data changes are managed by the tasks along the work process with fully automated quality and completeness checks executed by the computer supporting the data update operations between the central data storage in the background and the work process operations.

This final development stage will enable:

- standardised mechanisms to store, archive, authenticate access, transfer, preserve, curate, certify and interpret railway data;
- improved availability of primary digital data sources;
- a shift away from approaches based on the secondary sources which are often incomplete and incorrect;
- use of the data as the central element for the professional facility management
- improved analysis, acquisition, visualisation of data.

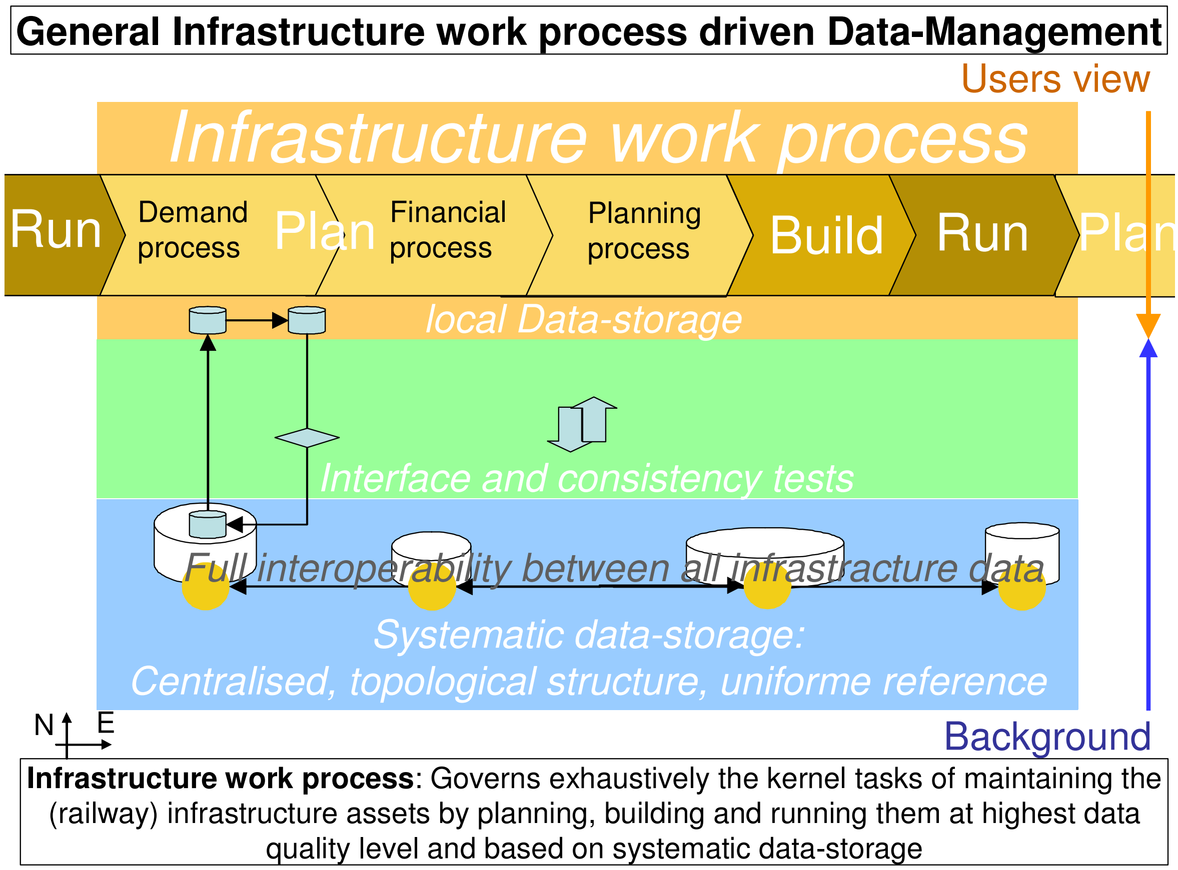

Fig 9: Final development step of work process support at railway infrastructure

4 RAILWAY PROJECT 2009

The main goal of the “Railway Project 2009” was to outline the conditions required to achieve interoperability of railway infrastructure data all along the European Railway lines based on absolute coordinates.

The international, interdisciplinary expert team started by analysing this goal from three different points of view: Geodesy, GIS and some specialised domains from the railway.

The outcome was then presented in a three-slides-summary for each domain.

4.1 Geodetic view

The Euref representatives first gave a rough overview of the progress in the introduction process of the European coordinate reference ETRS89 (Fig. 10)

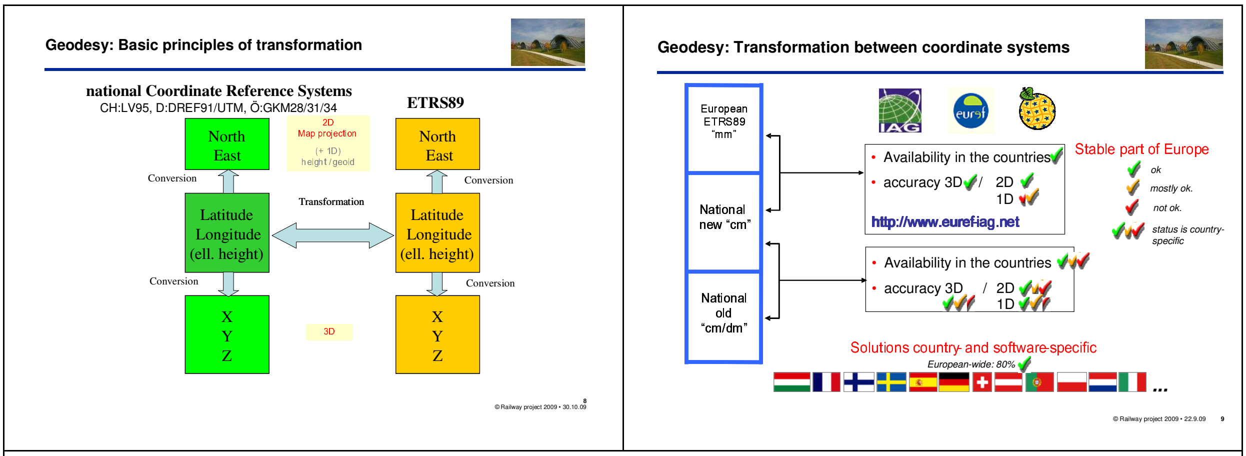

Fig 10. Euref report about the introduction of the European coordinate reference system ETRS89.

- ➔ ETRS89 is acknowledged by almost all European countries. The European commission recommended using ETRS89 as common coordinate reference system for Europe.
- ➔ Interoperability and data exchange between countries via ETRS89 / GRS80 is the only useful approach.
- ➔ Reflecting the actual reality in the different countries, map projection shall remain in the country responsibility.
- ➔ Coordinates are static (no time-dependent coordinates) valid for longer periods – except for local instable areas. Reality is, that many countries still have "distorted" old reference frames. Mid-term goal for almost all European countries is it to achieve an undistorted national reference frame which is directly in ETRS89 defined or which is aligned to ETRS89 by a simple translation. These “absolute coordinates” are suited for track machine guidance without alsways adapting the track to the local situation.
- ➔ Transformation “old frame” – “new frame” should be possible with a grid-transformation (NTV2) which is consistent with a national transformation method (Polynomial, Helmert, Finite Elements, …) on a precision level depending on the demands which for railways is 1cm;
- ➔ Transformations cannot resolve the problems of errors in the surveying / local networks.
- ➔ Solutions need to be developed in order to handle geometry changes with invariable circle radii and clothoides after coordinate transformations.

In a second review EUREF experts described their position in more detail as follows:

EUREF is responsible for the reference frame realization in Europe. With the introduction of the European Terrestrial Reference System ETRS89 an important basis exists. This was possible with the usage of the GPS technique, which allows precise coordinate estimation on a global/European scale. Most European countries supported this approach and generated in the years since 1989 reference frame realizations (ETRFs) mainly based on GPS campaigns. Many countries defined their new reference frames directly in ETRS89 or closely aligned to ETRS89. Due to the development in satellite geodesy, national coordinates were generated at different times and different reference frame realizations (ETRFyy).

Several years ago the infrastructure for reference frame realizations moved from passive classical markers to active permanent GNSS stations. This is obviously visible in the increased number of permanent stations within the European Permanent Network (EPN) and in the increasing number of national permanent stations. Positioning services are able to provide the national reference frame in real-time. Today, the geometric 3D-coordinates of the new reference frame realizations are consistent for the stable part of Europe on the 1-3 cm level (1-sigma rms). Fixed transformation parameters to all realizations of the global ITRS (ITRFxx) are available from the IERS. Therefore, ETRS89 is a success story and widely acknowledged as the basis for geo-information in the EU. Concerning the conversion of 3D-coordinates into plane coordinates 3 different map projections are defined European-wide.

More complicated is to establish the link between European heights and the national heights, which are based on physical heights or leveled heights contrary to geometric heights of the ETRF reference frames. The uniform European vertical reference frame EVRF2007 was published in 2008. Precise transformations to the national height systems do not yet exist for many countries. The release of a precise European geoid is planned for 2010.

Parallel to the newly defined reference frames, old coordinate reference frames, which have distortions of several meters compared to the "absolute" ETRF coordinates, exist in all countries. In general, in all European countries the transformation between old and new reference frames is defined and different tools are provided by the mapping agencies or GNSS reference station providers to the users (web-transformation, dll's, off-line programs). The definition of grid files, describing the distortions usually with a grid-spacing of about 1 km, is a software-friendly, standardized (preferably NTV2-format) solution. Nevertheless, a quite big variability of software solutions and country-specific solutions exist solving the transformation with slightly different accuracies (cm till dm accuracies). This is true for the plane position transformation as well as for the height systems and the geoid as the link between physical heights and the geometric heights.

4.2 GIS view

Facts and questions:

➔ Great degree of dependence on data-distributors, specially the cadastre (federal states, cantons, communes):

  – SNCF actual situation: transformation with centimetre precision (< 5 cm) from the reference frame expressed in the new RGF93/ETRS89 system to the old reference frame.

  – ÖBB actual situation: National historically grown Reference Frame MGI (3 GK projection zones M28/M31/M34). Local, regional and NTv2 Transformation from ITRS/ETRS89 to MGI available.

  – DB aim: ETRS89, federal states are changing at the moment.

- SBB aim: Frame/System LV95/ETRS89 on basis GeoIG[3] → year 2016.

➔ Referencing to ETRS89 must be possible based on the coordinates of the federal-state-coordinates-reference frames LV95, DREF91/UTM, GKM28/31/34

➔ Large effort for the adaptation of legal systems is needed due to the high number of connected systems and related post processing.

➔ ETRS89 for all data or only for submitting/defining the interfaces/services?

➔ ETRS89 implemented in track-maintenance-machines?

Implementation:

➔ The chronology and the road-map of the change have impact on the required efforts

- High risk during the change due to possible inconsistencies!
- Suppliers and projects have to be taken into account

➔ All phases (planning, projection, building, maintenance,..) have to be integrated and supported

➔ Isolated solutions are critical when several independent internal GIS-Solutions exist

- should be specially investigated in the implementation plan to ensure better integration

➔ Meta-Data (including aspects of quality, quantity and data model) are needed

- Reference/interfaces to other systems (e.g. SAP)

➔ A uniform coordinate-system is necessary but not sufficient! In addition the following elements are needed:

- Data-Model and regulation framework (geometrical and topological properties of the data-structures for all data-sets
- Quality-Concepts for Databases
- Standards for Interfaces
- Update concepts: Sustainable maintenance of all data is required

➔ „Non-GIS-departments“ (e.g. SAP-User) are to be convinced

- arouse the interest/understanding for data harmonization through work-flow approach and process considerations

➔ Influence of INSPIRE: Pressure for the usage of standardized coordinate-systems and data specifications.

4.3 Specialised railway domain view

Track domain – technical requirements:

➔ 1cm-domain: Reliable steering of the Track-Maintenance-Machines requires tension-free and controlled reference points. (Accuracy, neighborhood and reproducibility issues are to be successfully solved).

[3] GeoIG ist he abbreviation for the Swiss national act on Geoinformation

- ➔ ~10cm-domain: Track and official surveys must agree on best possible solutions– **How do we imagine this?** The coordinates of the track must be related to the official fixed geodetic points. Tensions must be identified and not integrated. (Keyword: best connection to the national survey).
- ➔ The quality of the railway track reference points must be registered in a clearly defined reference-system.

Track domain – economy:

- ➔ The quality requirement for tracks justifies the cost for ensuring the reference points. They must be continuously checked within the track maintenance process.
- ➔ An additional value could be achieved by the provision of simply accessible reference points which are also usable by the official survey (e.g. when using such points countrywide along the track lines generating a sort of "back bone effect").
- ➔ Decisions on proceeding in the railway practice:
  - Follow-up workshop in spring 2010 in Salzburg (the exact date will be communicated by the organiser ÖBB end of 2009)
  - To promote the experience exchange in the operational railway environment: Test lines for implementing coordinate based track data crossing the national boundaries.

Signalling domain:

- ➔ For the position of signalling objects a precision of „dm" is sufficient.
- ➔ The current project INESS (Integrated European Signalling System) defines standardized tools for data-preparation. This might be an additional economic argument for a high quality, uniform coordinate reference.
- ➔ With ETCS as it is specified now an intermittent data transfer is operated. It enables the calibration of train born odometry. Can the same results be obtained through satellite based positioning?

5 DEEPENING DISCUSSIONS

Based on the results of the expert work, feed-back was given by the track industry and by UIC as following:

5.1 Track industry

- ➔ **Actual situation**
  - No cross border, uniform data representation of absolute, coordinate based track data available.
  - Absolute referencing of tracks is still operated through fixed points on catenary masts:
    - In many countries absolute GPS-coordinates for track referencing exist at least partially.
    - Correct, complete, precise, net-wide coordinate data for track machine guidance exists manly for Switzerland.
  - In spite of the available precise GPS navigation techniques direct GPS driven track guidance diminishes productivity because GPS is not permanently available along the

railway track (tunnels, close buildings, roofing etc.) This perturbation can cause precision loss or errors. Establishing proof of the achieved quality of corrected track position must at least be considered to be problematic.

➔ **Practical requirements**

- Rapid work through and precise positioning of the track in track construction and track maintenance.
- High productivity and work quality of the track machines. N.B. the locking breaks available for the track machines diminish in duration and in number. The exploitation difficulties are an important cost driver.

➔ **Outlook– the advantages**

- The different systems for the coordinate-based workflow are manageable by largely automated work processes.
- Thanks to uniform data, no more country specific customising of track machines or education is needed.
- The measuring devices and systems can be implemented more easily.
- The application of the working methods is simple.

5.2 UIC

UIC mainly focused on the following aspects:

- The formulation of a "Memorandum of Agreement on Geo- Reference based on ETRS89". This actually exists in draft status. It is planned to serve as basement for deepening discussions at UIC Infrastructure management level.
- The track expert group will examine the question of introducing the "absolute coordinates" as a topic for 2012 onwards.
- The high-speed experts identified the system approach character of absolute coordinates and its large interdisciplinary potential. They asked to be kept informed about the ongoing work.

6 SOME PERSONAL FEED – BACKS

6.1 Experts

From official Cadastre, Jürg Kaufmann (international cadastre expert)

The ideas developed by the experts of the "Railway project 200d9 " follow the trend of building models of the reality, which is as well the base for the further development of cadastral systems. Like the cadastral objects, the railway objects will be defined by their geometry. This allows it to attribute non-geometrical data to the railway objects and to handle the data belonging to a certain object in an unambiguous way. This is conforming to the method used in the cadastre domain. One precondition is the clear modeling of the data describing the objects in a way that everybody involved understands the same. The easiest common denominator is the geometric description of the objects which is objective, while legal or financial terminology changes from country to country. Railways are normally regulated by national laws. It can be expected, that also certain railway data will become a part of the modern cadastre systems documenting public-law restrictions as outlined in the FIG publication Cadastre 2014.

From Euref, Elmar Brockmann (Swisstopo), Robert Weber (TU Wien)

For railway companies it is essential to make use of these new technologies which have the potential to optimize many work processes (see section 1). Certainly, solutions may still need to be developed, because of the high demanding accuracies ("absolute" coordinates with centimeter accuracies combined with "relative" accuracies of the track in the order of some few millimeters). Challenging solutions in the field using the satellite navigation technique but also solutions for transforming the track geometry from various old or new coordinate reference systems into the GIS data bases need to be developed and need to be implemented. As long as these new methods are not yet operational, it is recommended, to keep the thousands of reference points along the tracks

From ÖBB, Arnold Eder (GIS responsible)

There are only few surveying experts employed by ÖBB, most of them active in the project domain (covering the tie of local point clouds to the national coordinate system; cadastre) but also in the fields of frame realization (GNSS Positioning Service) and Research&Development.

The super-structure is of mayor importance but interoperable concepts are missing particularly as the use of absolute coordinates is concerned.

Nevertheless: the experts still active at ÖBB are searching to get project work interconnected with maintenance by optimising them already in very early (pre-project) phases.

Referring to the “Railway project 2009” new track projects could be referenced to ETRS89 and possibly older projects could be transformed too, this by integrating them into the existing geodetic reference. This leaves all options for future, absolute coordinate based maintenance work remain open.

To make use of products of the nationwide operating GNSS Positioning Services (primarily EPOSA, APOS) by referring local projects to the datum information provided by these services (by means of RTK-corrections, station coordinates and RINEX-observation data) will allow to connect local networks to the ETRS and tie them almost tensionless to the national coordinate system.

The introduction of a unique, net wide coordinate reference system (similar to DB-Ref) especially for the track maintenance should be examined.

Concepts for absolute coordinate referenced tracks, central data base data storage etc, should be developed together with the internal ÖBB services (research, superstructure etc) and external experts.

6.2 Industry

From Track industry Matthias Manhart (Sersa Group), Bernhard Lichberger (Plasser)

The development of track machines with their implemented measuring system and user interfaces can be simplified if a harmonised data model with standardised interfaces exists for all European countries. Measuring systems wont need data conversions for distinct countries and will be usable Europe wide without changes. The education of the collaborators can be simplified for data management, interfaces and documentation.

Stable and precise data (according to EN13231) are the request to meet the high precisions requested by the railway infrastructure administrations within the very short maintenance intervals.

6.3 Management Feed-back

From SBB, John Hegarty (Head of Finance, Signalling & Telecom Systems)

The use of geodetic data for referencing the position of railway tracks has led to clear benefits in the construction and maintenance processes of these assets. Standardising this method at a European level and extending the approach to other areas of railway infrastructure opens up a range of potential opportunities for the rail transport system from the perspective of the infrastructure providers as well as industry partners.

In addition to the potential improvements in the track quality and in the operational processes, the approach offers a solution for a standardised referencing system for all asset databases. Once implemented this would enable the correlation of all asset data in the company to be automated and thereby revolutionise the asset management processes.

To achieve a solution which is feasible in practice and sustainable over the long term will require several areas of expertise and the cooperation of many stakeholders. The initiative taken by the Group of Experts with the Railway Project 2009 was a major first step in the right direction.

From DB, Jens Hartmann (Head of technical track domain)

Until April 2010

7 CONCLUSIONS: THE QUESTIONS TO BE DEEPENED

From Théo Engel, organiser of the "railway project 2009"

During three days the experts met in summer 2009. Besides this the "railway project 2009" was exclusively conducted on e-mail and telephone basis. The result of that modern communication tool based dialog is of very high level and the overall view given at chapter 6 allows to outline the ongoing way.

Given this excellent communication "culture", I allow myself to give my personal view about possible ongoing steps, being sure that they will easily be corrected/completed by the dialog partners if necessary.

A kernel outcome of the work done is the finding of the double character of absolute coordinate based track data:

- They serve as reference data and are the basement of data interoperability between the European railways and between different data base contents.
- They serve as track machine guidance data and are the basement of a future, largely automated track maintenance use, guaranteed at track construction precision level and referenced to the absolute coordinates frame ETRS89.

The "railway project 2009" opens two crucial questions with technical character:

- Is the geodetic measuring industry (Leica, Trimbel, …) interested/are the railway companies and/or the track industry willing/able to develop a GNSS based measuring device allowing a track positioning with 2mm repetitive precision? Today such devices doesn't seem to be operative yet for a net wide use for track maintenance;
- Will the companies be able to deliver the incontestable, track live cycle lasting proof of the stability of the reference points used for a continuous positioning of track machines with 2mm precision? To deliver that proof it makes sense to invite the companies which today use that method, as a daily support of their net-wide maintenance work, i.e. SNCF (France), SBB (Switzerland) ev. Holland.

It is of utmost importance to establish consolidated answers to these two questions before planning further ongoing steps heading towards the operational putting into practice of the absolute track coordinates.

Of course it also makes sense to work in parallel to deepen some organisational questions.

- At supra company level mainly: the question of standardizing the track data structure and the data transfer formats for future compulsory use within all the railways;
- At individual company level mainly: the dialog between railways and the national EUREF representatives to establish and administer optimally the reference coordinates set, to guarantee a sustainable quality at least during the live cycle of the track and ideally, being recognised by both partners as UNIQUE coordinate reference.

Do all these questions need the establishment of a common ongoing strategy to optimise the work between the different partners in order to get cross-frontier and cross-data base reference data interoperability into the railway practice?

I hope that a practical answer to that question will be the next operational step on the way forward.

Acknowledgment1

Together with all the persons which have actively participated to the elaboration of this text, following persons participated to the operative part of the “railway project 2009”.

From the railways

- GIS: Allmann Gerd-Dieter and Jacoby Hans, both from DB, Moser Dominic from SBB
- Signalling: Winter Peter
- Track: Beck Andreas and Lücking Lars, both from DB

From the Research&Development

- Carosio Alessandro and Gnägi Hans Rudolf both from ETH Zürich, Stanek Heinz ÖBB

From the Institut Géographic National (France)

- Duquenne Françoise

From INSPIRE

- Giger Christine, Swiss delegate

MANY THANKS to all of you. You made a big work!

Bern, January 21, 2010.

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BIOGRAPHICAL NOTES

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Actual tasks:

- Methodological support of the specialised services in their inventory of the financial facility database. The task is supposed to end in interconnecting financial and technical data as key element of the work process approach described in this text.
- In charge of questions about railway geodesy at SBB and internationally.

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1974 – 1980:	Tätigkeiten in allen Bereichen der Ingenieurgeodäsie in der Bundesbahn Direktion Frankfurt
1980 – 1995:	Leitung der Abt. Grundlagenvermessung der Bundesbahn, Direktion Frankfurt
1987 – 2009:	Teilnahme an div. universitären Fortbildungsseminaren im Bereich der physikalischen Satellitengeodäsie und Grundlagenvermessung
1994 – 1999:	Aufbau des ersten satellitengestützen Grundlagennetzes im Bereich der Niederlassung Mitte der neuen Deutschen Bahn AG
1999:	Beurlaubt aus dem Beamtenverhältnis des Bundeseisenbahnvermögen, Wechsel und beruflicher Eintritt bei der Deutschen Bahn AG Netz Zentrale in Frankfurt
1999 – 2005:	Projektleiter des Projektes NXO / Umsetzung ETRF 89 im gesamten Bereich der Deutschen Bahn AG
2006 – heute:	Projektleiter im Projekt RailNav (Erstellung digitaler Streckenatlas und hochpräzise Messzugnavigation)

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Jürg KAUFMANN, Switzerland

Education

- Federal Institute of Technology ETHZ, Dep. Mathematics/Physics, 1962,1963
- Federal Institute of Technology ETHZ, Dep. Rural Engineering and Surveying, Diploma 1967
- Diploma of a Business-School
- Licence as Swiss Federal Licensed Surveyor, 1981

Languages

German, English, French, Italian

Consulting Experience

- Member of the Project Management Board of 'Reform of the Swiss Official Cadastral Surveying'
- Consultant to national, cantonal and municipal authorities for Cadastre and GIS in Switzerland
- Consultant for Cadastre Projects in Belarus, Ukraine, Kosovo, Serbia, Macedonia, Azerbaijan
- Chief Technical Advisor for Georgia
- Consultant to the Government of the Principality of Liechtenstein for implementation of the National Geoinformation Infrastructure
- Member of the drafting committee for the Law on Geoinformation

Professional Experience

- Since 1988: Independant Consulting Engineer, KAUFMANN CONSULTING
- 1981-1988: Keller Vermessungen AG, Switzerland, Chief Executive Officer
- 1979-1981: Federal Institute of Technology Zürich, Senior Assistant Geodesy and Land Information Systems
- 1970-1979: Digital Ltd, Zürich, Informatics Services for Engineering, Director
- 1967-1970: Federal Institute of Technology, Zürich, Assistant Land Management and Cadastre

Main international and national mandates and awards

- Delegate of the Swiss professional organization of surveyors in FIG, Commission 7, Cadastre and Land Management
- Member of working group 'Statement on the Cadastre'
- Chairman of working group 'Cadastral reform and procedures; Cadastre 2014‘
- President of the Swiss Association of Geomatics and Land Management since 2005
- Honorary member of FIG since 2006

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