MAKING IT HAPPEN
BUILDING AND DEVELOPING TRACK QUALITY MEASUREMENT (TQM) TROLLEY

Edward Len PhD, MInstCES, MPWI

INTRODUCTION

Network Rail standard of measuring Track Quality was set by the HSTRC (High Speed Track Recording Car). In the last couple of years Network Rail introduced HSTRC successor, packed with modern technology highly sophisticated NMT (New Measurement Train). Both trains deliver excellent results on high speed measurement and less accurate on slow speed recording.

The purpose of building the TQM was prompted by an idea of extending existing standard onto the areas where high speed measurement are less reliable. In technical terms it meant building a system capable to emulate the HSTRC standard (Fig. 11) from the data recorded at walking speed.

1. WHAT IT IS AND WHAT IT DOES ?

TQM stands for Track Quality Measurement recorder. TQM measures the following track geometry parameters (Fig. 3):

- **Horizontal Versine (on various chord length)**
- **Vertical Versine (on various chord length)**
- **Longitudinal Level (on various chord length)**
- **Cross Level**
- **Gauge**
- **Distance along the track**

Fig.1. TQM (Track Quality Measurement) trolley.

By using those parameters TQM software is able to emulate the Network Rail track quality standard (Fig.11) set by HSTRC or NMT.
In order to bring closer to the reader all perplexities encountered in designing and manufacturing of a TQM, the Short Base Measurement (SBM) terminology needs to be adopted to describe a problem (Fig. 2) which finally had a biggest impact on TQM concept design solution. SBM measuring references are physically constructed rigid bases of user definable length in a range from 1 to 4 metres. Various track measurements are taken against those bases which are simply pulled or carried out onboard of a transporting trolley frame (Fig.3)
SBM disadvantages are well known to the Engineering Surveying profession. All surveyors are trying to avoid short referring bases (RO) in their surveying practises in order to secure accuracy of the detail surveyed. TQM intension, however, was directed in the hart of this problem by trying to succeed in carrying the survey in a “wrong” way (short RO reference) and hoping to deliver the picture of a long shaped track alignment. Those are the stages of a struggle and thinking encountered in order to make this project successful.

2. THE IMPACT OF ACCURACY ANALYSIS ON CONCEPT DESIGN

+/- 2mm		+/- 2mm		+/- 2mm		+/- 2mm		Accuracy goal for LB (Long Base) generated Horizontal Versine (on 10 or 20m chord)
10m	20m	10m	20m	10m	20m	10m	20m	
1m		2m		3m		4m		Short Base length (SB) used
100	400	25	100	11	44	6	25	Projection Scale $(LB)^2 / (SB)^2$
+/- 0.02	+/- 0.005	+/- 0.08	+/- 0.02	+/- 0.18	+/- 0.05	+/- 0.32	+/- 0.08	Expected Short Base (SB) measurement accuracy

Compiled results on 1000m radius curve			
SB	HV magnit.	SB HV Accur.	20m HV Accuracy
1m	0.12mm	+/-0.005mm	
2m	0.50mm	+/-0.02mm	50mm +/-2mm
3m	1.12mm	+/-0.05mm	
4m	2.00mm	+/-0.08mm	

To read the figures follow the example: In order to achieve +/-2mm accuracy in software generated HV on 20m chord length a singular HV reading on 2m long SB chord has to be measured with accuracy of +/- 0.02mm. This translated on curve of 1000m radius - 2m SB HV of 0.5mm +/-0.02mm gives 50mm+/-2mm gen. 20m LB HV

Fig. 2. Expected Short Base measurement accuracy.

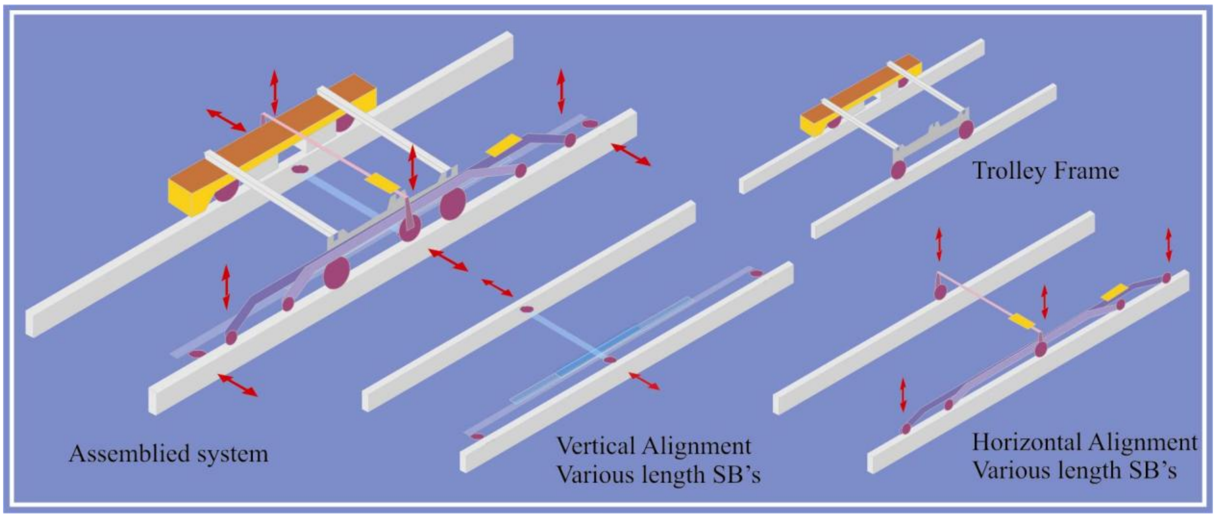


Fig. 3. TQM concept design.

3. ADDRESSING SB CONCEPT SOLUTION

Advantages:

- **Stable reference base (no loss of accuracy on pivoting)**
- **Ability to introduce reciprocal reading corrections**
- **Ability to use suitable base lengths for various application**
- **Calibration parameters stay with the SB (not with the trolley)**
- **Flexibility in choosing calibration place – office or track**
- **Lightweight TQM modules can be easily carried onto the track or the metro station**

Disadvantages:

- **Measurements are not always going to be taken in the right place (Fig.5)**

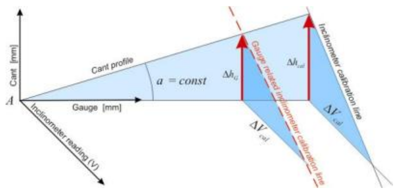


Fig. 4. Variable gauge Cant errors.

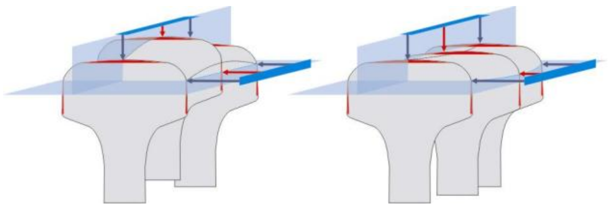


Fig. 5. Vertical and Horizontal unevenness against TQM SB's.

<u>Note:</u> When the out of square railhead section is measured using rigid SB's the following errors are introduced to the recorded data: Vertical Unevenness creates non existing Horizontal Unevenness and accordingly Horizontal Unevenness creates non existing Vertical Unevenness (Fig.5).

To eliminate this inconvenience the following software corrections were introduced:

- **Hor. Versine readings are correcting Vert. Versine readings**
- **Vert. Versine readings are correcting Hor. Versine readings**

Additionally high cant, gage variation and trolley acceleration negative influence on reading quality was removed as follows:

- **Cross Level readings are correcting Longitudinal Level readings**
- **Time stamp readings (interval reading acceleration) are correcting Longitudinal Level readings**
- **Gauge readings are correcting Cross Level readings (Fig.4)**

All other type of errors (trolley frame free movement errors) were removed mechanically

4. ENSURING ACCURACY

By performing calibration operator gets confidence to the system ability and to the quality of the data recorded.

The following aspects of TQM calibration was taken care of:

- **Software controlled calibration procedure (Fig.7)**
- **Calibration tools development**
- **Assessment and elimination of ambient temperature negative effect on reading quality**

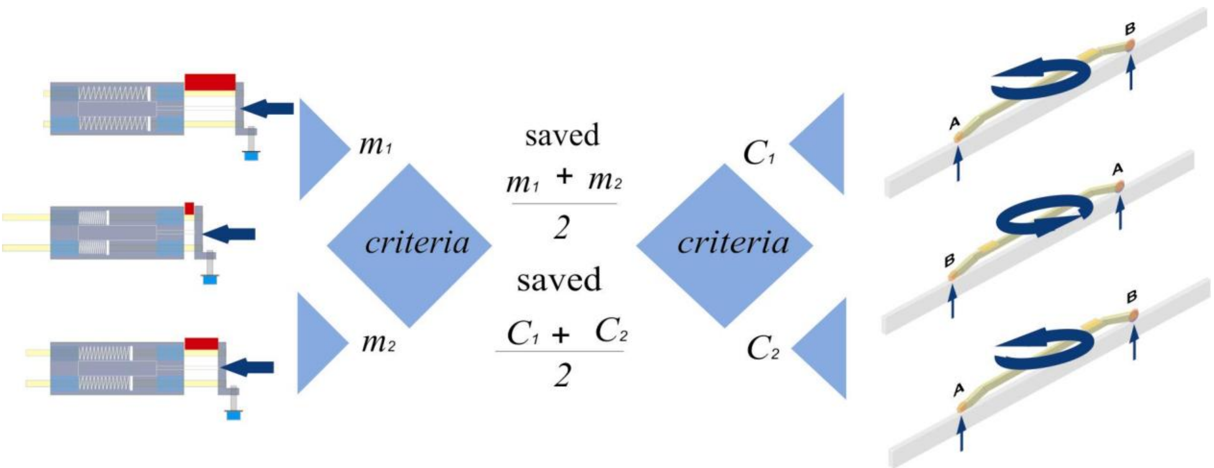


Fig. 6. Conversion factor and Zero calibration procedure.

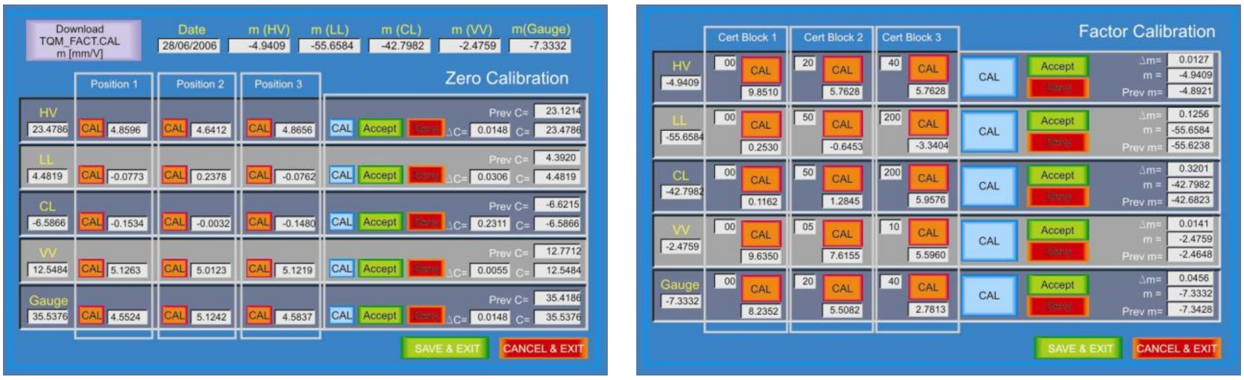


Fig. 7. Software controlled calibration procedure.

5. DATA SAMPLING AND DATA PROCESSING

Data sampling was set @ 0.1m interval with sampling rate of 14 Hz (walking speed recording). All eight TQM channels are recorded at this speed. With respect to the lengths of SB used this solution has produced SB[m]/(2*0.1)[m] numbers of independent sets of overlapping versine data (eg. 3m SB delivers 15 sets of data). Translating this into the memory consumption it takes approx. 1mb of memory per 1km of survey data recorded.

Calculation stages:

- **Applying calibration parameters to the raw observation**
- **Applying all data corrections**
- **Calculating most probable readings @ 0.5m interval from readings recorded @ 0.1m**
- **Compiling Alignment and Top rail profiles (Left and Right rail)**
- **Applying 35m and 70m wavelength Butterworth filter**
- **Calculating SD**
- **Validating SD against the Network Rail SD Track Quality criteria**
- **Generating all obligatory Track Quality reports**

5.1 Hardware platform

A desire to record, process and transmit the data directly from the field to the office (or tamper) concerned pointed out to use a Windows based, standard PC equipped with suitable DAQ card.

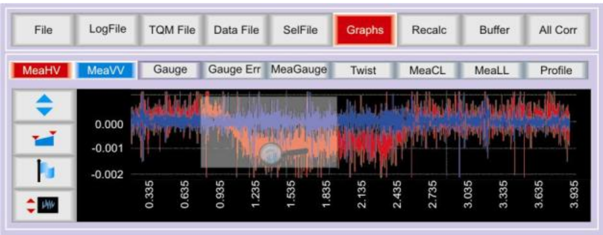
After long struggle in finding a reliable solution, Itronix tablet PC housing National Instruments DAQ card, was chosen.
This set of hardware copes favourably with all type of vibrations, weather conditions and magnetic fields encountered during track survey.

5.2 Software Solution

The following package of TQM software was developed for TQM system: TQM Calibrator, TQM Recorder, TQM Editor and TQM Viewer

Fig. 8. All channels table form recording.

Fig. 9. Selected channel graph recording.



TQM Editor v1.7.0.72 User:MJL
Computer:TQM Date:Sat 23 Sep 2006

4 09:21:47 Original TQM file: RL11.TQM
4 09:21:47 Copying TQM file to: Current
4 09:21:47 TQM file RL11.TQM in standard format
4 09:21:47 Existing backup file not overwritten: \BKP\RL11.TQM
4 09:23:45 Reversing locations
4 09:24:19 Updating all recordings of channel MeaVV by 0.25
4 09:26:55 Interpolating channel MeaCL between (-14.6880, -1.23)
4 09:27:40 Setting nominal gauge to 1435
4 09:27:40 Recalc
4 09:29:07 Applying post-meas. Correct.

Fig. 10. Fully controlled data editing.

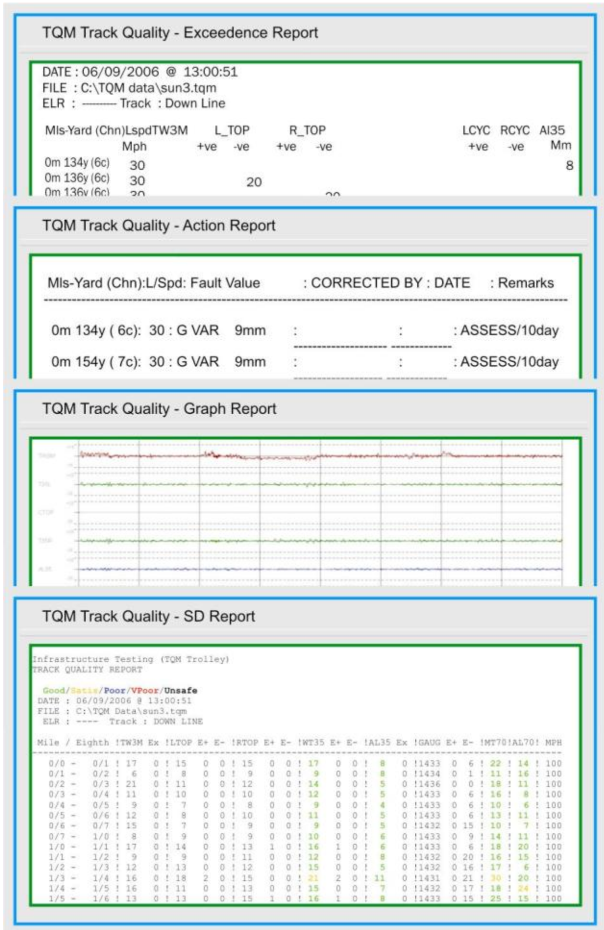


Fig. 11. TQM Track Quality reports.

6. ERRORS, TESTS AND COMPARISONS

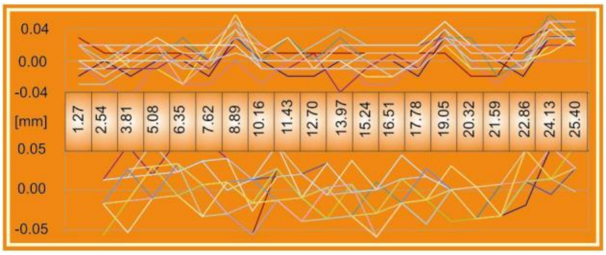


Fig. 12. Certified blocks measurement.

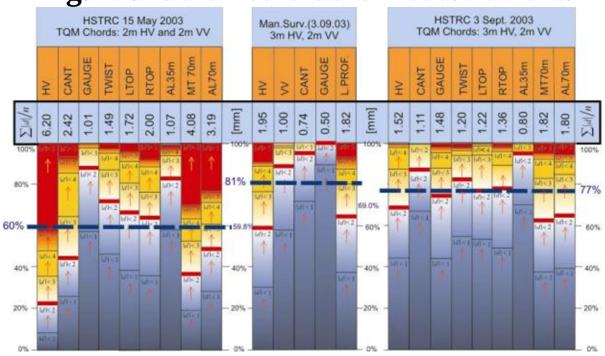


Fig. 13. Survey differences: HSTRC, Manual Survey, TQM.

Twenty Certified Blocks (CB) were measured in 20 series using calibrated TQM modules for HV and Gauge. Graph shows maximum discrepancies of all measurement. Lines represent series of observation. For clarity not all of the series were plotted on the drawing

Survey differences: High Speed Track Recording Car (HSTRC), Manual Survey, TQM data comparison (Fig.14) Dash blue line represents mean value of differences of +/-2mm between relevant data recording of Manual Survey and HSTRC survey. Test was carried out on 100m/hr track including reverse curves of 2000-3000m radius

7. RECENT CASE STUDY

Most recently TQM played a major role in the Network Rail PALAS project by validating the position of a Fixed Points coordinates and measuring track quality to assess the effectiveness of a Palas system. For this purpose a Total Track Survey (TTS) technique was developed using onboard mounted Leica 1201 Total Station.

TTS is a surveying technique which delivers track spatial data from the survey observations, recorded from arbitrary points rather than from a previously coordinated stations (Fig.14).

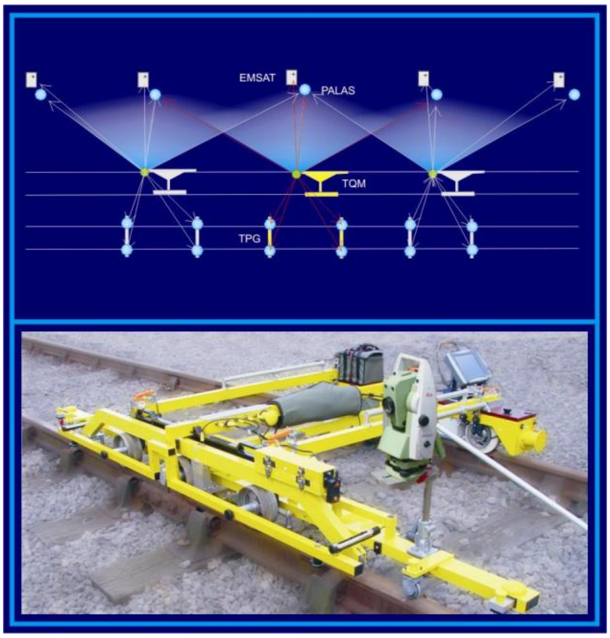


Fig. 14. Overlapping Versine (Leica 1201).

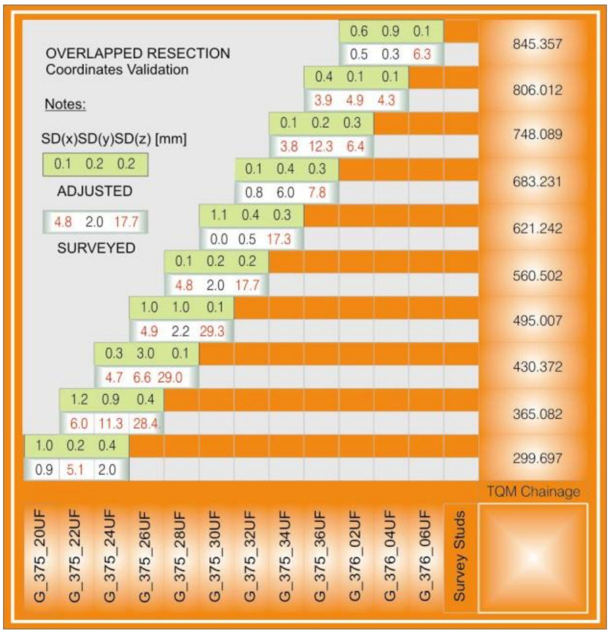


Fig. 15. Studs coordinates validation.

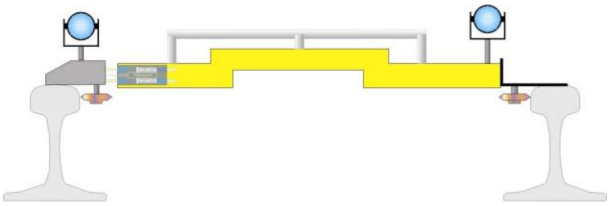


Fig. 16. TPG (Track Prism Gauge).

For this purpose a TPG (Fig.15) was developed and the n4CE codes (Application in Cadd software package) were written to automate coordinate generation for both rails.

Illustrated in Fig.18 surveying procedure shows TQM stopping position where all overlapping resections to the stud prisms and relevant TPG observations were recorded. n4CE derived SD resection validation (Fig.15 – white box numbers) permits prompt identification of an erroneous coordinates (red numbers).

Such overlapped resection observation can be further "least square" adjusted using network adjustment software packages (STARNET).
The main advantages for using this surveying technique over the traditional ones are:

- **increased accuracy of derived coordinates (no instrument centring errors involved)**
- **shortening survey time**

In one survey run TQM TTS technique delivers: Full Track Quality data, validates integrity (or derives new) Track Control coordinates, validates or derives all Fixed Points data.
More detailed information about TQM system can be found in: www.rail-tqm.co.uk

REFERENCES

Bałuch H.: Ocena nierówności toru odniesionych do długich baz pomiaru. (Materiały) X Konferencja Naukowo-Techniczna „Drogi Kolejowe '99" Spała 1999.

Bałuch H.: Kierunki usprawniania diagnostyki nawierzchni kolejowej. (Materiały) Pierwsze Seminarium Diagnostyki Nawierzchni Kolejowej, Gdańsk 1999.

British Railway Track. "Design, Construction and Maintenance" – Permanent Way Institution (1993).

Herceg E.: "Handbook of Measurement and Control" – Shaevitz Engineeing, Pennsauken, N. J. USA.

Izydorczyk J., Płonka G., Tyma G.: „Teoria sygnałów" HELION 2006.

Jakubiec W. I Malinowski J.: „Metrologia wielkości geometrycznych" WNT Warszawa, 1999.

Len E.: „Pomiar geometrii osi toru systemem TQM Mk3" (Materiały) Trzecie Seminarium Diagnostyki Nawierzchni Szynowych (Gdańsk – Jastrzębia Góra 2001).

Len E.: „Emulacja Standardu oceny stanu jakości toru kolejowego systemem TQM", Szóste Seminarium Diagnostyki Nawierzchni Kolejowej, Gdańsk – Jurata 2004).

Len E.: „Panika czy też sposób na sukces". Szóste Seminarium Diagnostyki Nawierzchni Kolejowej, Gdańsk – Jurata 2004.

Len E.: „Analiza dokładności kształtu geometrycznego toru na podstawie pomiarów realizowanych sposobem ciągłym przy użyciu metody krótkich baz pomiarowych". (Praca doktorska) Politechnika Gdańska – Wydział Inżynierii Lądowej – 2004.

Len E.: Papers in Civil Engineering Surveyor (November 2006), Permanent Way Institution Journal (2006).

RT/CE/P/038 Track Geometry: Management of Recording of Immediate and Urgent Actions – British Standard.

RT/D/P/085 "Management of Track Force found by Track Recording Vehicle" – British Standard.

Skórczyński A.: "Podstawy obliczeń geodezyjnych" PPWK, Warszawa 1983.

Skórczyński A.: „Rachunek wyrównawczy" PPWK, Warszawa 1983.