Opportunities for Improving Interfaces between Railway Engineering Analysis Tools

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OPPORTUNITIES FOR IMPROVING INTERFACES BETWEEN RAILWAY ENGINEERING ANALYSIS TOOLS

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KEYWORDS: Railway system, analysis tools, tools interaction,

ABSTRACT
Railways are complex systems, which utilize many engineering disciplines in order to ensure their safe and efficient operation. Railway engineers make use of ever improving analysis tools to control the performance of various parts of the railway system. Often these tools have become efficient but highly specialized. For example, vehicle engineers use powerful dynamic simulation packages but the information these provide are not always fully utilized in work carried out by infrastructure engineers who are using their own software tools.

The EPSRC funded TRAINS project is studying the Railway System as a whole. As part of this the Rail Technology Unit at MMU is investigating the links between tools used by different engineering disciplines in the railway field. An overview of the TRAINS project is given in [1]. A database of tools has been set up and is being used to establish links between tools and, more importantly, gaps where tools are not interfacing as they could. The structure of the database is outlined in this paper.

This project provides an opportunity to investigate the interaction between design, maintenance and operation of the vehicle and the effect on the track. In this paper we show how a sample system model is being set up which links some of the identified tools to demonstrate the interfaces. This system tool is then used to establish the effects of changes in one part of the system (such as the wheel-rail interface) on other parts of the system (such as interaction with the infrastructure).

INTRODUCTION

The privatisation of the UK's main railway network has resulted in the separation of responsibilities for various technical aspects of the railway system. This has inevitably resulted in utilisation of different tools in different parts of the railway system, which in many cases do not communicate directly with each other. As a consequence of the wide range of technical issues and problems being faced in the system, a significant number of tools have been employed to assist the various partners in fulfilling their responsibilities.

These tools can be in the form of simulation or analysis packages, specialised techniques or equipment. While some of the tools can be utilized in various engineering disciplines, the majority of these tools have been developed to perform a specific task in a certain area of the railway system. As the first stage of this project a survey of all tools is being carried out and the tools have been categorized and stored with certain relevant details.

THE TOOLS DATA BASE

The whole railway system has been divided into groups and subgroups in a way that the structural position of each subgroup in relation to other subgroups and whole system can be identified easily. For each subgroup, all commercially available tools can be identified and described. This provides the opportunity to identify gaps in each subgroup where appropriate tools are needed, and secondly study the possibility of improving the existing tools in a way that they could interact with each other in other subgroups. Figure 1 shows the top level of this tools database.

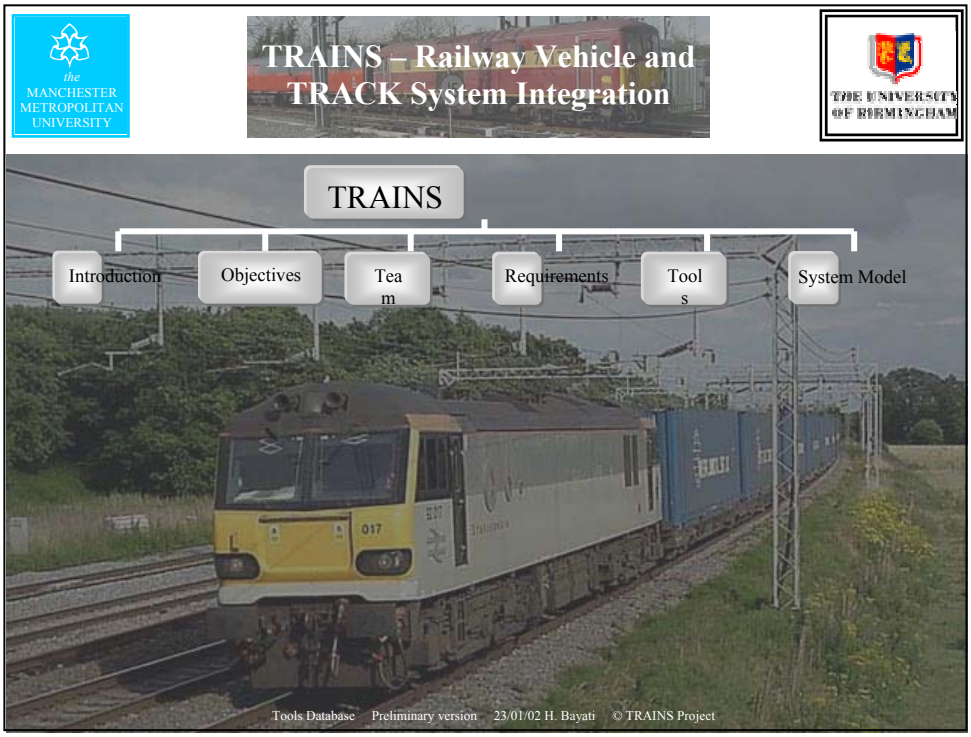

Figure 1: The TRAINS tools database, top level menu (V – I = Vehicle – Infrastructure, W – R = Wheel – Rail)

The issues concerning the railway system are not limited to the design, operation and maintenance of vehicles and infrastructure. Other factors including, environmental impact and management are important and are included as separate sections.

A major boundary that exists between the infrastructure and the vehicle operating companies is the wheel/rail interface. The integrity of this interface is crucial to the safe and successful operation of the railway network as a whole. This has resulted in significant number of tools developed for this particular area. As can be seen in figure 1, the Wheel-Rail interaction section is located in the center of the chart. On the left and right hand sites of this center point, the units built upward and downward of this interface respectively

Table 2 presents a brief overview of the subgroups underneath the top level. It can be seen that there is some overlap between the areas covered but the dynamic links in the database will bring the user to the correct tools. An example of a subgroup menu is shown in figure 2.

Main Groups	Subgroups
Infrastructure	Bridge, Tunnel, Station, Signal, Overhead, Loading, Inspection, Maintenance
V - I Interaction	Signaling, Loading & Unloading, Pantograph, Maintenance Area, Gauging, Impact
Vehicle	Power Supply, Transmission, Inspection, Maintenance, Braking System, Suspension, Air Conditioning, Materials, Design, Health & Safety,
Wheel	Materials, Design, Inspection, Maintenance
W – R Interaction	Dynamics, Noise, Friction, Stress, Control System,
Track	Rail, Sleeper, Switches, Fastenings, Maintenance,
Substructure	Slab, Ballast, Subgrade, Maintenance
Environment	Economy, Traffic, Employment, Noise, Health & Safety,
Management	Cost , Staff, Supplies, Administration, Training, Asset Management, Control System, Maintenance, Health & Safety,

Table 1: Subgroups for each main group of units and areas in railway tools database

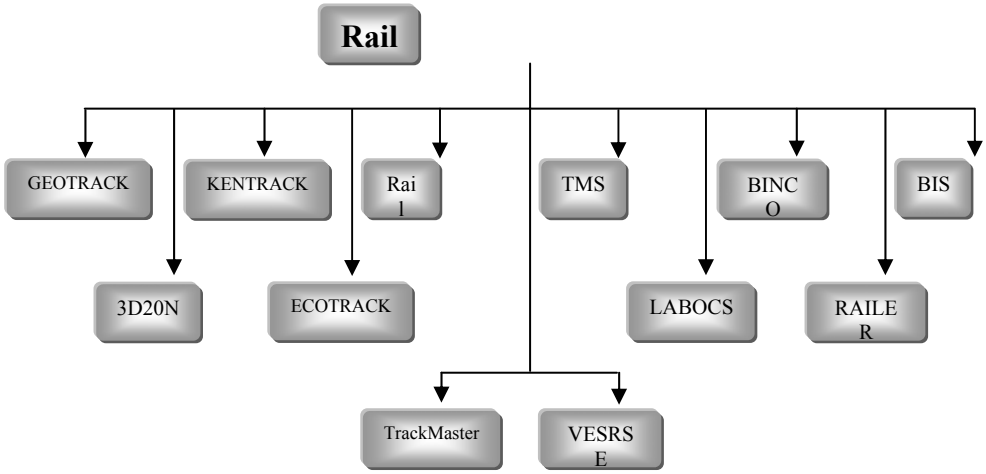

Figure 2: List of simulation and analysis Tools associated with the subgroup Rail

The database is continually being updated and currently contains more than 250 tools but it is not yet considered a complete representation of all existing tools. Links to tools have in some cases been made to more than one category, for example many of the simulation and analysis tools presented in figure 2 can also be usually can be considered under the subgroup 'Substructure' as well. This is expected, since the level of wheel and rail interaction will mean that inputs and outputs to tools in this area are closely related.

The same argument can be applied to other tools in neighboring units and provides a framework for future development in tools such that they could take into account all these interactions. Some widely used tools such as vehicle dynamic simulation packages, are linked to almost all the subgroups associated with vehicles in the railway system. Figure 3 shows the chart for the subgroup 'Suspension' that includes several well-known commercially available vehicle dynamic simulation packages.

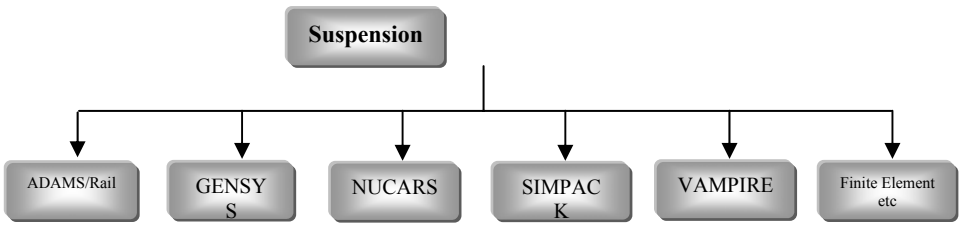

Figure 3: List of simulation and analysis Tools associated with the subgroup Suspension

A standard format has been developed to describe the most important parameters of each tool in the database including the main inputs and outputs. This format is shown in figure 4

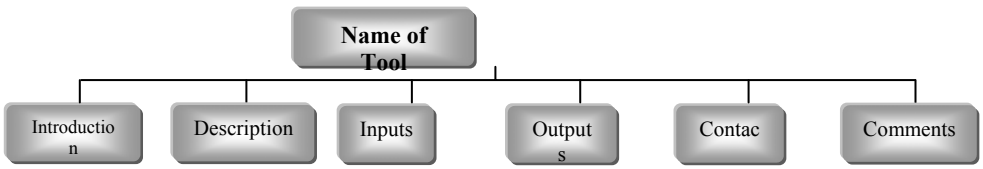

Figure 4: Format used to provide the information concerning all tools in current study

The inputs and outputs are essential for linking the tools together in the second stage of this work. The comments section allows information about the use of the tools, levels of expertise required, level of validation etc. These comments could be from tool suppliers or users or from relevant benchmark studies (eg [2]).

SYSTEM ANALYSIS

In the second stage of this project the tools database is being used to analyse the ways that the different tools link together and to identify any gaps that may exist between tools that have the potential to be linked. A number of key inputs and outputs to the whole system have been identified in a trial run of this process and the results are presented here.

Key inputs :

a) Gauging data ; position of track, position of lineside structures, tolerances, route data
b) Vehicle data ; Masses, inertias, geometry, stiffness and damping, characteristics of suspension components
c) Wheel data ; radius, position, gauge, vibration properties, roughness
d) Wheel+Rail Profiles ; Cross sectional profile, new and worn
e) Track data ; top, alignment, cant, curvature, gauge
f) Substructure data ; Stiffness of track, ballast and subgrade.

Key output :

a) Structure impact ;
b) De-wirement ;
c) Ride comfort ;
d) Critical speed ;
e) Derailment ;
f) Vehicle fatigue ;
g) Noise ;
h) Track forces ;
i) Wheel+Rail wear ;
j) Contact stress ;
k) RCF (Rolling contact fatigue);
l) Corrugation ;
m) Ground Vibration ;
n) Ballast settlement ;

The following examples show how the database is used to follow links from the key inputs to the key outputs using inputs and outputs of the existing tools.

Figure 5 shows the links leading to the desired output of structure impact. In this case three tools have been used.

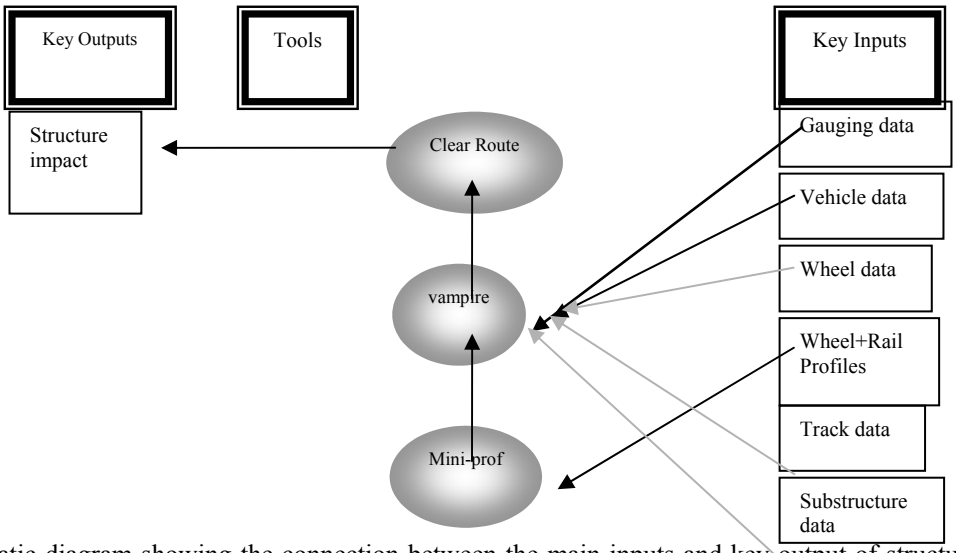

Figure 5: A schematic diagram showing the connection between the main inputs and key output of structure Impact through number of the tools. The grey arrows indicate a weaker link.

MiniProf Wheel and rail is profile measuring system, VAMPIRE is a vehicle dynamics package and ClearRoute is a structure gauging package.

The tools icons link directly to the database and can provide further information. The linking arrows also contain information relating to the effectiveness of the link between the tools or inputs or outputs.

A second example is shown in figure 6. In this case the desired output is ride comfort and it can be noted that there are two separate routes to this output available. The 'Ride Mon' tool allows direct measurement of accelerations in a vehicle and provides an alternative or can give confirmation of the values given by the VAMPIRE vehicle dynamics package.

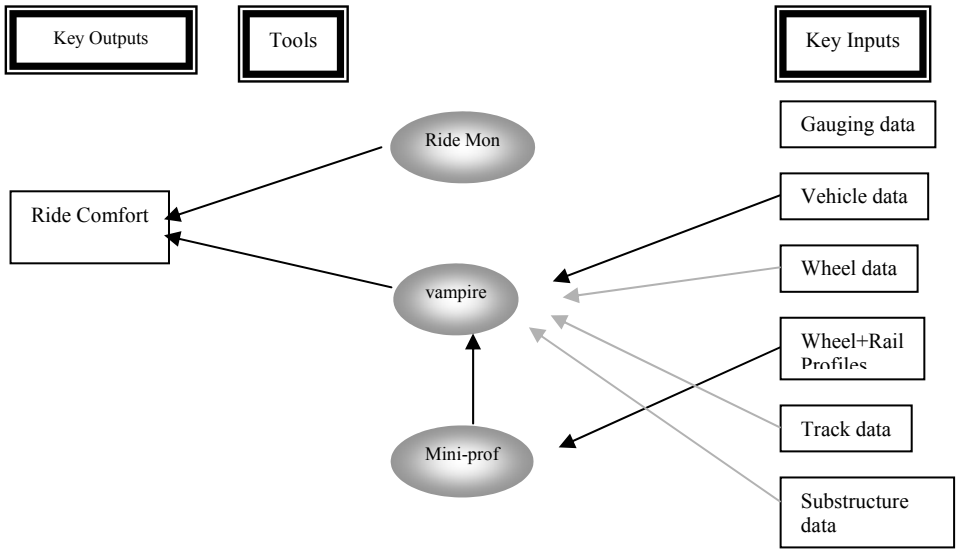

Figure 6: A schematic diagram showing the connection between the main inputs and key output of Ride comfort through number of the tools. The grey arrows indicate a weaker link

CONCLUSION

A database of tools used in the railway system has been set up and is being populated. The complete database will include information on the inputs and outputs to all the major commercial tools currently in use and will allow an analysis of the effectiveness of these tools to produce useful outputs.

In particular the database is now being used to identify gaps between existing tools or poor linkages, the improvement of which could lead to more effective transfer of useful information between engineering disciplines.

REFRENCES

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[2] Iwnicki S. (ed) 'The Manchester Benchmarks for Rail Vehicle Simulation' Swets & Zeitlinger B.V. Lisse 1999, (ISBN 90 265 1551 0)

The Rail Technology Unit

Rail Technology Unit

Manchester Metropolitan University

The **Rail Technology Unit** based at **Manchester Metropolitan University** carries out research and consultancy into the dynamic behaviour of railway vehicles and their interaction with the track.

We use state of the art simulation tools to model the interaction of conventional and novel vehicles with the track and to predict track damage, passenger comfort and derailment. Our simulation models are backed up by validation tests on vehicles and supported by tests on individual components in our test laboratory. We are developing methods to investigate the detailed interaction between the wheel and rail.

January, 2004
Simon Iwnicki
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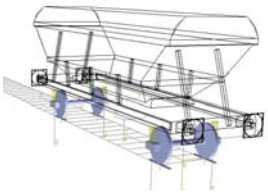

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- **Railway vehicle suspension dynamics**
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  - Lab and field testing
- **Wheel-rail interface modelling**
  - Profile design
  - Wear
  - Rolling contact fatigue

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