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TRAIN PERFORMANCE AND SIMULATION

Paul Martin

Comreco Rail Ltd
St Marys Court
39 Blossom Street
York, YO24 1AQ, U.K.

ABSTRACT

Simulation provides a valuable tool in both the design of new infrastructure coupled with assisting in the process of translating a railways business aspiration into a technical specification. The simulation system can be used in many forms: 1) As a single train run to assess traction performance over a given infrastructure or assumptions of the physical characteristics of a new line, 2) To assess a range of signalling systems in order to identify the optimum solution to meet a service aspiration, or 3) To evaluate proposed timetables and the interaction between the trains at a complex junction or in major terminals. This paper seeks to demonstrate the varying levels of simulation and their key role in the support of railway projects and the benefits from integrating simulation tools.

1 INTRODUCTION

Railway systems, whilst now old and established in most peoples eyes, actually continue to develop and grow. Generally, they are emerging from a period of stagnation and contraction to rapid growth in traffic as both passenger and freight traffic is won by rail from the congested road alternatives.

Growth is resulting in new trains being ordered and improvements in capacity being designed for new and existing railways. All this growth has to be controlled to ensure that the proposals meet the design requirements and offer a cost effective solution and value for the money.

Simulation systems are being used to evaluate proposals and validate the final designs prior to any major expenditure. Growing sophistication with the available simulation systems is leading to the individual aspects of simulation being integrated to provide a comprehensive planning and development tool.

This paper seeks to demonstrate the varying levels of simulation, their key role in the support of railway projects, that no single aspect should be considered in isolation and, finally, that the final simulation must be undertaken using a full traffic simulation. It also demonstrates how the integration of all aspects of scheduling and simulation will work to the benefit of planners.

2 SINGLE TRAIN SIMULATION

As a simulator must apply the laws of physics to the calculation of train movement all the commercial simulators must be very similar in the calculations they perform. The key differences must therefore be in the user interface and the data entry. To be a commercial success it is essential that these systems are user friendly, not too data hungry and simple to use.

The time taken to enter data is a key element when it comes to being commercially viable. To this end it is possible to apply typical values to some aspects of the calculation in lieu of detailed information. Work is now progressing with a number of railway organisations to build databases of information, which will speed simulation in the long term whilst using more detailed information.

Basic Simulation: In the simplest of simulations a balance of forces takes place. The locomotive applies a force to overcome resistance and accelerate the train until a balance is reached where the accelerating forces match the resistance forces and a constant speed is maintained. This balancing speed will be maintained until the tractive force is removed and replaced by a breaking force to overcome the trains' momentum to stop it.

Speed: The performance of a train will normally be designed so that the balancing speed is above the basic line speed on level track and allowing for some value of rising gradient. The degree of performance provided on a rising grade will be influenced by factors such as cost etc. Thus the train will accelerate to the maximum permitted speed.

Speed of trains within the simulation may be controlled by four parameters:

- Line speed.
- Train Maximum Speed.
- Conditional Speeds set by signalling or other operational considerations.
- Speed set by route selection

The active speed limitation at any one time will be the lowest for that train at its current location. When traversing a restrictive speed the lower speed is applied to the train for the length of the restriction plus the length of the train for the majority of speed restrictions.

Added to this data will be a profile of the route featuring curvature and gradient. This is included in the profile controlling the line speed and may feature additional speed profiles allowing the application of differential speeds. This data will also allow for trains with differing braking capability (with respect to signal spacing) and for trains capable of curving at higher speed such as tilting trains.

Time: The time any given train takes to travel between any two points on the network is of interest to both the simulation and scheduling systems. From a single train simulation the time taken for a train to run between stations can be determined which provides the basis of the scheduling system.

The simulator produces all the possible stopping patterns of times that form the basis of full timetable.. This is then repeated for each train formation to determine the full range of timing loads. Table 1 below shows the range of times generated by the simulation for any two stations. With a similar list for all station combinations, and for each train type, the basic building blocks for developing a complex timetable exist.

Table 1: Station Times

Station A to B	Time (secs)
Start to Stop	**703**
Start to Pass	**683**
Pass to Stop	**689**
Pass to Pass	**669**

Timetable: Timetables were originally produced manually in conjunction with hand drawn train graphs. This process relied on the experience of the timetable compilers to judge what was practicable and for the resolution of conflicts. This process meant that, by and large, the timetable developed slowly with each successive timetable issue featuring only small changes and incorporating lessons learnt through practical operation of the last timetable.

This process was ripe for improvement by the use of computers and the first generation of scheduling systems have been in use for some years. These can replicate the graph drawing process in a much shorter timescale and cope with larger changes in a single iteration. A drawback of these first generation systems is a limitation on the size of network they can handle. With a system the size of the UK rail network the scheduling exercise had to be broken up in to zones. This creates problems, typically, that a train crossing many zonal boundaries cannot be viewed in its entirety. The result of this is that the impact of changes proposed by one zone cannot be viewed in other zones.

First generation scheduling systems made the best use of the computing power available at the time. The latest generation of scheduling system is currently being commissioned with RailTrack in the UK. This is a customised version of Comreco Rail Ltd's TrainPlan™ system. It is capable of all that the first generation systems could do and more. It can now handle the whole of the UK trains services in one database. This allows complete cross-zone trains to be viewed whilst access controls limit authority to alter these trains.

The system supports the bidding process under which train paths are now allocated on the privatised railway as well as short term planning. TrainPlan™ produces ready to use train graphs and print ready timetables and is being developed to fulfil a number of other business aspirations. Despite all the added functionality the basis for calculation remains the run time between stations for each train type. These run times are still generated by performance simulation.

Energy: A detailed electrical supply network model will be necessary to fully evaluate the energy needs for an electrified system. However, as part of the iterative process towards developing the full model the single train simulation can provide a simple indication of energy requirements. This can explore the energy requirements of different speed profiles over a given infrastructure.

It can be demonstrated that a 5% extension on run time can produce energy savings of up to 20% on a suburban system. If coasting is used to extend the journey, typically 5% for a suburban railway, there is scope for a late running train to reduce its coasting to catch up on schedule.

3 PROJECT DEVELOPMENT

The railway as a whole is made up of many facets that interact to produce the whole railway. It should be obvious that the design of each element must consider the others.

In a very extreme example it is obvious that the track design team and the rolling stock designers should agree a fundamental such as gauge at a very early stage.

There are three basic elements to the design of a railway that could be considered as separate disciplines. These are Civil Design, Signalling Design and Operations design. Whilst it is possible to consider these individually they are so interlinked that an integrated approach makes more sense. The development of a project will start with an iterative process considering each of the topics detailed below. After the first simulations the process is refined and simulated to develop the optimum solution. Finally this process leads on to multi train simulations to verify that all the aspects of design will work together to support the planned train service.

Civil Design: The civil design for a new project or an upgrading project starts from broadly the same point. For a new project, there would be some idea of the proposed alignment whereas for an upgrading project this would be the existing infrastructure.

Initial simulation runs will calculate the theoretical maximum speeds derived from the alignment data and by applying rules for cant and permissible cant deficiency. Additional constraints can be factored in at this stage such as speed restrictions applied for tunnels as a result of air pressure limitations. From this initial model the speed profile is refined to develop a smooth profile.

Providing and maintaining infrastructure for trains to operate on is an expensive business. Generally, providing infrastructure for trains to run at high-speed cost more than it does for low speed. It therefore follows that it is sensible to match civil line speed with the speed capability of the trains using the lines. Historically the railway infrastructure was built in at a time when present day speeds weren't even imagined. This provides a constant challenge to the designers trying to get every last scrap of speed out of the infrastructure.

Signalling Design: The signalling system is required to be able to support the aspirations for both speed and capacity. The governing factor in signalling design is the ability of the train to stop i.e. the braking distance.

Operations and Capacity Design: The operational requirements often start with a mixed and conflicting set of requirements resolution of which requires compromise and an integrated solution across all of the disciplines. The following headings briefly expand some of the considerations:

Speed: Fundamentally the speed at which a train can run is limited by its ability to stop. The distance required to decelerate from line speed to a standstill will determine the signal spacing which will, in turn, affect the line capacity. Thus a better braking performance will allow faster speeds for any given signal spacing.

Where signalling already exists faster speeds have been achieved by improvements in brake performance. Examples of this in the UK are the HST which can stop from 125 mph on lines originally signalled for 100 mph and the APT which had sophisticated hydro-kinetic brakes to stop from 150 mph in the same distance. Operationally it is likely that not all trains will run at this maximum speed. Business targets with a mix of fast express passenger service, lower speed passenger services and slower freight trains may ultimately influence the speed.

Headway: Headway is the separation between successive trains. This is usually expressed as a time and is based on the following train having clear signals. In its simplest form this is expressed for similar trains running at the design speed. Once again this is governed by the signal spacing. Whereas for speed greater signal spacing allows higher speeds this increases the headway. To give a close headway signals need to be closely spaced. When the railway carries a mix of services the fastest trains determine the standard headway and slower trains will extend this minimum headway.

Paths: Prior to a detailed timetable being available design will be done on the basis of the number of trains per hour over each line. The minimum headway divided in to a hour will give the number standard paths per hour e.g. a 3 minute headway will give a 20 paths per hour capability. These paths are standard paths. Slower, or stopping, trains are subsequently described as using two or more paths reducing the "trains per hour" capacity.

Conflicts: The slower or stopping trains are now seen to conflict with the fast trains either delaying them or reducing the number that can be run. Consideration must now be given to resolving these conflicts using simulation packages whilst trying to fulfil the business aspirations. Options for mitigating this problem may now be considered. There are many permutations of this, two are suggested here:

Flighting of fast services: If a slow service is taking up line capacity one solution is to flight the fast services to run in a group in advance of the slow service and leaving a gap before the next flight of fast trains. This is only a part solution as it assumes there is some spare capacity to allow the gaps in the fast service. Another disadvantage is that eventually the flight of fast trains will catch up with the previous slow train and be delayed. This strategy may also fail as a regular business aspiration is even interval "clock face" departures.

Slow lines or loops: An alternative is to provide slow lines or loops at the stations for the stopping passenger trains or away from stations for the freights. The optimum solution for slow lines is to ensure that the turnouts allow the trains to switch at speed and then decelerate off the main line.

In practice, as available capacity is used up, an iterative development takes place. Initially trains are flighted. Next loops are added where the flights catch up with the slower trains. More loops are added until the final solution is to provide separate slow lines.

Junction Optimisation: Thus far the train performance has been considered for a single train. That train has, as it ran through the infrastructure, passed through junctions and stations. There are a number of factors to be considered:

Junction occupancy: As soon as more than one train runs there will be locations where more than one train wants to be at any one time. It is the job of the signalling to prevent this from happening. In so doing the signalling will control, along with the train speed and the timetable, the junction occupancy. The headways and capacities as previously discussed were for plain line. As soon as a junction is encountered these can be seriously affected to the detriment of the overall performance.

Clearance times: The key to limiting the impact of a junction on the capacity of a route is to minimise the time taken for a train to clear a junction. The clearance time is the time taken for a train to travel from the signal controlling access to a junction to the point at which it releases the route to others. The time is determined from the moment the front of the train passes the approach signal to the moment the rear of the train clears the track circuit locking the junction. A number of factors will influence the clearance time:

Position of the approach signal: The junction is locked from the moment the approach signal for a given route clears. If the signal is far in advance of the junction then the time taken for the train to reach the junction will be significant.

Length of the Junction: The length of the junction will affect the time the train takes to cross it. In principle the junction should be kept as short as possible. In practice this will be affected by the design speed, high-speed turnouts being longer. Other physical constraints such as bridges and level crossings may affect the location of turnouts.

Speed through the junction: The design speed of the turnouts will greatly influence the length of the junction. A high-speed junction will be much longer than a low speed one. If a high-speed junction is specified efforts should be made to ensure the trains cross it at speed to minimise the time the junction is occupied.

Clearance Point: The clearance point is the trailing end of the last track circuit locking the junction. Until the rear of the train passes this point the junction will not be released to other trains. Therefore, the clearance point should be as close as possible to the junction. In larger and more complex junctions elements of the junction may be released progressively as the train progresses across it.

Length of the train: The length of the junction is from the approach signal to the clearance point. As the junction locking is not released until the rear of the train passes the clearance point the effective length of the length of the train increases the junction. Length therefore becomes significant. Considering the combined effect of these factors it can be seen that the design of a junction can have a significant effect on the performance of the railway as a whole.

Refined layouts: The optimum design of a track layout for a junction will depend on the planned service in terms of both stopping pattern and capacity. For any given service pattern there will be a number of options mixing low speed junctions for an all stopping service, adding more costly high speed junctions to facilitate fast non stop trains and, ultimately grade separated junctions to remove diverging trains from conflicting flat junctions. This staged development demonstrates that the final solution must consider the full train service over the whole infrastructure with full interaction between trains, signalling and the timetable. Hopefully, it also becomes clear that it is inadequate to assume that all the trains' run as scheduled.

4 TRACTION AND ROLLING STOCK

Simulation of a single train over a network allows the performance of that single train to be evaluated and run times established. Many factors should to be considered in designing the rolling stock for a given line:

Power Source: Will the train be electrically powered or should diesels be used? On an existing railway this may be decided by what is already available unless the train supply is part of an electrification scheme. There is the possibility that diesels would be specified on an electrified railway. If the operator has a short franchise a diesel unit may have a greater value when re-leased due to its wider operating possibilities.

Regenerative Braking: Assuming an electric train is specified will it have regenerative braking? Can the supply network accept regenerated energy? Will the type of train and service produce worthwhile returns on the investment in either reduced energy, better braking or reduced wear?

Maximum Speed: What maximum speed is the train service being designed around? Aspirations for the future should be considered in deciding the maximum speed.

Weight: The weight of the train will have a significant effect on the trains' performance**.**

Route Availability: The weight, expressed, as the axle load, will determine the route availability of a train. line will have a route availability determined by the load rating of bridges etc. Route availability is often stated as an index number. The train must have the same, or a lower, "route availability" index to be compatible.

Train Resistance: The train resistance will be comprised of elements representing the drag. The design may need to consider techniques to reduce this such as articulation and streamlining**.**

Length: The length may not directly affect the performance of the trains in terms of journey time for "normal" length trains. However, it may have an impact in a number of ways. There may be restrictions on platform length at some, or all, stations. The length of the train and its speed will govern when the interaction of many trains will be significant when the occupation times for track sections are considered. An abnormally long train will take longer to clear PSR's as the restriction applies until the whole train is clear of the restriction.

5 POWER SUPPLIES

Electrical engineers have to consider the supply network for an electrified railway. For a new railway the initial design will be based on the theoretical power consumption of a single train multiplied by the number of train paths. From this theoretical demand constraints will be added to refine the design. Those constraints will be such factors as the location of the utility feeders.

On an upgrading project the constraint will be the existing supply and its strength. The initial studies can only be a guide to the capacity and only a simulation of the full service can test resilience of the supply. This will mimic the capacity of the supply with the dynamic interaction of all the trains with the proposed train service.

Factors to be considered are:

Substation Sizing: The initial calculations will determine the required capacity of feeder stations and consider such constraints as any limitation in the capacity of the supply from the utility. It is almost inevitable that the supply points will not coincide with the optimum designed location.

Voltage Drop: Voltage drop in the supply for the proposed loading will govern the ideal feeder station placing. Once the actual feeder station locations have been determined the voltage drop calculations will be revisited to ensure that the supply remains robust. If not already dictated the voltage drop calculations may influence the voltage and distribution system chosen for the railway.

Energy Costs: Again if not already dictated the cost of energy distribution may influence the choice of supply. Long distance railways favour higher voltage systems to minimise the investment in equipment and to reduce the effects of voltage drop.

Regeneration: The use of regenerative braking can have a major impact on energy costs. It can also have benefits for the rolling stock engineer in reducing the frequency with which friction brake components require attention. The system design will have to incorporate extra equipment if regeneration is planned however the supply capacity should be designed assuming that regeneration does not occur. Provision of regeneration thus becomes a balance between the projected energy saving and the cost of providing additional trackside and train equipment. The benefits to be gained from regenerative braking will depend on the type of train service planned. A frequent commuter stopping service will give a higher return than a fast non-stop service. Simulation provides the basic data to undertake such evaluation.

6 MULTI TRAIN SIMULATION

Initially single train operation has been considered but the railway is a large and dynamic network where many trains interact with the infrastructure, signalling and each other. As the previous discussion has progressively demonstrated all the aspects contributing to the operation of the railway as a whole need to be considered to ensure the full picture is modelled and that the results are robust. A natural progression leads in to the simulation of multiple trains, delay modelling, variable performance and many other variables. The following items demonstrate the complexity achievable with modern simulators. It is by no means an exhaustive list.

Complex Timetables: When considering a single train only one performance calculation is required. On the real railway it is highly probable that there will be many trains of differing performance and operating over different routes. A multi-train simulator can simulate these by storing the performance information for many trains and routes and referring to the ones relevant to a particular train in its timetable entry.

Varied Stopping Patterns: Trains run to differing stopping patterns even if they are of the same type and on the same route. The stopping pattern may be entered as scheduled stops in the timetable. For metro type operations regular and standard station stops can be specified as a standard dwell time applied irrespective of the schedule.

TrainPlan Downloads: The timetable is the key to drawing the entire route, train type and schedule data together for each train. For even the most basic railway this amounts to a vast quantity of data. Often the area being simulated will be a small part of a greater network with the total data being stored in larger timetable databases**.**

TrainPlan™ is a train scheduling system that would contain the entire schedule, train and geographical data for a network for train service development. Timetable information filtered for a given area or service group can be extracted as a direct import to the RailPlan™ performance simulator. TrainPlan™ can also read and convert data from its predecessors. This facility saves a considerable amount of time in preparing timetables for simulation. Currently some additional data has to be added manually to give RailPlan™ some information not currently available in TrainPlan™. This requirement will be minimised in the near future.

Variable Loads: For light rail and metro operations with a high passenger density the variation in train weight can have a significant effect on the trains' performance and the energy consumption. With a time based passenger profile for each station the weight of trains can be altered. Thus a train starting in the suburbs only lightly laden can progress through the city centre loading up to crush and then emptying as it runs out in to the suburbs on the other side can be modelled. This effect can be varied with time of day.

For a heavy rail operation the weight of the train as affected by passenger loading is usually of a lower density and less variable it, therefore, has less impact on the simulation performance.

Variable Performance: The performance of trains as determined by the tractive effort curve may in practice vary. Performance curves are generally available to cover the basic service conditions, which for an electric train would mean a range of supply voltages and possible supply limitations. Other variables such as weight length, auxiliary load etc are taken account of to produce the required train characteristics.

Coasting: Another aspect of train operation utilised in day to day operation is the use of coasting. This may either be for the energy saving benefits or to provide some resilience in the train service by planning to use coasting but allowing full performance to be utilised if the train is late. In the simulator coasting may be controlled by either the separation of trains, as on a very frequent metro system, or by comparison of actual time to the schedule, or indeed by the use of trackside coasting board data predetermined to optimise energy saving.

Specific Delay Modelling: In analysing a proposed layout it is possible to identify key areas which, should they not be available, would have a serious impact on train services. The effect of the loss of this key area can be modelled allowing the impact of this loss to be quantified. The unavailability of any track may be programmed to happen for a specific time and duration or for a random time and duration within set rules. Having quantified the effect and thus the cost of such a disruption a case for parallel tracks or other maintenance measures may be supported. Such proposals can then be tested with the simulator in due course.

Random Delay Modelling: Only in an ideal world will all trains run exactly to scheduled time. Some trains will run to time, others will have very minor delays whilst a proportion may be quite seriously affected. These delays may have originated outside the area being simulated i.e. the train entering the simulation late, or from actions at stations within the simulation. In addition delays will be incurred from the interaction of trains. Whilst a train schedule may work comfortably when all trains run to that schedule this is not a true evaluation of the infrastructure. A simulation should test the resilience of the whole under perturbed circumstances.

Start Delay and Dwell Delay: The delays can be modelled as probabilities. These delays are of two types. Start Delay is the delay imposed on a train at the beginning of its journey be that where it enters from outside the simulated area or where it starts its journey within the model, say, at a terminus. Dwell Delay is a delay incurred at any other station stop within the simulation.

Random Seed Number: Random delays as used in the simulation cannot be truly random, as it is necessary to have repeatability in the simulator operation. This is required so that changes can be evaluated with the random spread of delays repeating up to the point where the change would have an effect.

Within the simulator the pseudo random effect is controlled by a “Random seed number” from which the randomness is calculated. Changing the seed number will change the delay pattern.

Variations in Power Supply: The power supply will be affected by the change in services in the traffic simulation due to delay modelling. In addition the electrical network may itself be changed to assess options on performance.

Power Limitation: The electrical simulation can either be allowed to draw unlimited power from the supply or apply power limitations at the rating of each feeder station. The power drawn from the supply will vary as a result of the delay modelling. In the worst case, for example, when a delay results in all the trains on a metro accelerating together, this could exceed the supply capacity. Modelling with the limits applied will determine the effect of this whilst modelling with the limits off will indicate required feeder capacity to cope.

Regeneration: Regeneration is beneficial both for energy saving and improved braking of trains. For it to be beneficial the supply system must be receptive. Typically this requires a mix of accelerating and braking trains.

In an example where delays resulted in all the trains drawing power at the same time the station spacing resulted in them braking together. This very quickly raised the line voltage to the point where it became unreceptive and trains were forced to use other braking methods. This gave the worst possible results for the power supply engineer but originated from the good intention of providing a better service by reducing headway allowing more trains. The new design headway happened to coincide with station spacing!

Network Configuration: With the addition of timed operation of switches to the electrical simulation the electrical network can be reconfigured during a traffic simulation. This may be used to simulate additional capacity being brought on line or the failure of supply.

Monte Carlo Techniques: Running a single day perturbed train service is informative but does not present a balanced view. In a single days perturbed simulation individual trains may be allocated long delays from the distribution tables. This would be unrepresentative of that trains typical performance.

Similarly, where the simulation is allowed to route trains dynamically in accordance with locking rules one day would be unrepresentative of the regularly used routing options. The solution is to run the simulator for more than one day. The simulator will run the simulation many times over applying a different random pattern each day. The random pattern is still keyed to the original “Random Seed Number”.

Ten days is a typical number of days to run. This will give a more typical spread of delays per trip run. Simulation runs of more days may be run to refine the results. The number of day's run is a compromise between refining the results and the available computing time, a ten-day simulation can be a lengthy task.

Results are produced for each days operation as well as summarised results for the complete multi day run. The simulator output will contain vast quantities of data on the running of trains. This will include:

Track Usage	Number of times a track is used
	Average speed
Signalling	Signals approached at Caution
	Signals clearing on approach
Trains	Number of each type run
	Average & Maximum Speed
Timetable	Delays per train
	Delays per trip
	Total and average delays

This information is available as a "per train", "per day" or summary output.

In a multi-day perturbed simulation the most telling result is the delay trains accumulate during the simulation in comparison with the injected start delay. A resilient track layout for the timetable being simulated is one where the end delay is the same, or less than the injected start delay. This demonstrates that, despite entering the simulation late, trains are not made later by the layout and may actually recover some time.

A simulation where the end delay figure is greater than the injected start delay suggests that the track layout is contributing to the delays of all the trains. The figures per train will indicate if any one trip is causing this delay, giving the opportunity to retime that train, or highlight which area of the network is causing the problem.

In the UK the performance regime is geared to "delay minutes" with compensation or charges being decided on this basis. With a cost per minute, even if different groups pay at different levels, the financial impact of a train schedule on a given track layout is indicated. This cost may influence alterations to the train service or justify investment to reduce the "delay minutes".

From the outset, with single train simulation, the performance of each aspect of the whole railway has been developed, initially separately, and then integrated to confirm and develop the relationships between each component of the "whole". The natural extension of this is to develop this simulation in to a multi-train simulation and then add in a simulation of perturbed operation. Only at this stage is simulation coming close to mimicking the real world.

7 ANIMATION

Results thus far discussed have all been text or numeric. It is these values that would be the key to making investment or design decisions however these make it difficult to actually visualise what is occurring in the simulation. Visualising what is going on is the key to understanding the figures and a key element in supporting a numerically based investment case.

The best form of visualisation is a dynamic view of trains running over the simulated infrastructure. RailPlan Animator™ offers this in the form of a representation of a typical Signalling Mimic diagram displaying the track layout and dynamically displaying the progress of trains through the system.

The animation is a post process on an output file created by the simulator allowing to be viewed independently of the simulator. All the controls typical of a video player along with zoom and speed controls allow areas of interest to be studied in detail.

8 SYSTEM INTEGRATION

Whilst having demonstrated the interaction of all aspects of the railway this has been done with separate simulation and scheduling system tools. At present this is achieved by using a variety of different simulation tools. Train scheduling, performance simulation, electrical simulations and visualisation tools have been considered. The first generation tools worked in isolation with separate models for each tool. The current generation has some provision for exchanging data between the systems. The future will see more integration to provide all these facilities in one simulation package.

RailPlan™, the performance simulator and PowerPlan™, the electrical simulator will be integrated to provide direct interaction between the power supply and the train performance. The mimic diagram used in RailPlan Animator™ may well become a substantial part of the data entry for RailPlan™. Simply drawing the network will allow the program to extract the data required for simulation. TrainPlan™, the scheduling system, and RailPlan™ will become integrated in data format and presentation allowing the easy transfer of information between the systems.

Achieving this requires a significant amount of development work with some elements having to migrate to alternative computer languages. This ideal will take time to achieve but it is being actively progressed. The advantages are too great to not take seriously.

An integrated system where all relevant data is available will allow quick assessment of all aspects of a proposed change. A planned new train will have its performance checked, its fit within the schedule assessed, impact on the supply network and energy costs reviewed and an animation of its interaction with the other trains viewed all in a relatively short space time. This will allow simulation to be used as a powerful tool in both the short and long term planning process.

Comreco Rail Ltd produce the systems in generic versions and as customised systems for clients adding any additional capabilities and interfaces the client requires. This has resulted in TrainPlan™ speaking Israeli and talking to Swedish signalling systems to control automatic route setting information from the timetable. RailTrack have adopted these systems as their standard and the desire to provide a fast, accurate and interactive planning tool is driving the development of the integrated product.

In addition to the systems so far mentioned management systems for allocating trains sets to schedules and then managing the crew rosters for these services are being developed and tested at the moment. Practical trials with train operators suggest a saving of 10% in crew costs alone is achievable.

9 CONCLUSIONS

Simulation will certainly play a greater role in the future development of railways and whilst powerful simulation programs exist for individual aspects of the design process it is clear that these do not show the whole picture. The way forward must be the multi train simulator modelling all aspects of the interactive railway. Unless the final stage of the development process features such a simulation based on the actual workings of the railway it cannot be really valid as verification that any proposal will work.

Building a comprehensive simulation model of a complex area entails a significant cost. However, compared to the cost of getting an initial scheme wrong, and subsequent rectification, it is a cost avoided at the projects peril. The current business climate requires engineers and designers to offer some guarantee that a scheme will work, offer value for the investment and deliver the required result. The “scheme” might be a major remodelling or the simple proposal to run an additional train. The requirement to assess the impact is the same and is contractually binding.

The main cost of building a simulation is in populating the infrastructure databases. Integration of the simulation systems is going reduce the repetition in this process and allow maintainable infrastructure records. Repeat run of a train or timetable on an established model is a relatively quick process. We are working towards integrated databases and simulation tools allowing very quick assessments to be made. In the future it could be possible for an operator to contact RailTrack with a request to run an extra electric train at short notice starting at a given time. In just a few minutes that train will have been timed, its performance checked and the energy assessed. The operator will be given the actual planned timings, advised that the proposed locomotive and load can maintain the timings and what the cost will be. Integrated multi-train simulation is the way forward. Considerable development will be seen in the near future.

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APPENDIX A SIMULATION TOOLS

This document discusses simulation in general and gives specific examples produced with three simulation systems produced by Comreco Rail Ltd.

Those systems are:

RailPlan™: is a train performance calculator capable of modelling all aspects of train performance with multiple trains operating. It is capable of modelling all current types of signalling either directly as a selectable option or by configuration to mimic the required operation.

Animator™ is a visualisation tool that presents the operation of the trains in a RailPlan model as an animation of the action presented on a mimic very similar to those seen in signalling centre.

PowerPlan™ is a post processor for RailPlan for the modelling of electrical networks and train electrical performance. This simulator can model both AC and DC networks modelling the circuit as either single impedance or as defined supply and return networks.

TrainPlan™ is a sophisticated timetable generator that works from given train timings as may be produced by RailPlan. TrainPlan produces printed timetables and train graphs ready for use. TrainPlan can also produce the necessary inputs for timetable driven signalling systems.

These are all mature products in commercial use around the world. The examples in this paper have been produced using the current versions of the software. Comreco Rail Ltd is continuously developing the software with a number of innovations planned between preparation of this paper and the residential school. The presentation at the residential school will use the then current versions of the software.

AUTHOR BIOGRAPHY

PAUL MARTIN is a senior engineer with Comreco Rail specialising in rolling stock performance and power simulation. Prior to developing specialisation in simulation Mr Martin gained wide experience in the railway industry building, commissioning and operating new rolling stock for a variety of railway organisations. Subsequently Mr Martin joined a major UK consultancy and advised on new rolling stock and operational issues.