Developments in Rail Simulators and Computer Based Training to increase training efficiency and effectiveness

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ABSTRACT: The incorporation of recent advances in computer software and hardware has allowed the development of new methodologies in the application of computer and simulator based training. Sydac Pty Ltd has recently upgraded and developed a number of simulators that provide new capabilities designed to increase training efficiency and effectiveness. The experience of QR in the use of Train Driving Simulators and Part Task Trainers as part of their competency based training and action learning programs has been a key element in the definition and refinement of the new functionality required to achieve training efficiency and effectiveness gains.

The underlying training effectiveness and efficiency goals, the new capabilities and functionality plus an outline of how these have been implemented in upgraded 3000 class electric locomotives console simulators and the new 4000 class diesel locomotives full cab mobile simulator are presented. A discussion of the success achieved since their introduction is included.

Objectives such as reduced cost of operation through features such as one switch powerup, 24 hours access, unattended “trainee only” usage, remote access and centralised control and monitoring of training from a remote location are discussed.

New capabilities introduced to meet the QR training objectives are explained. These include the trainee only operation, swipe card access and training performance logging system and the facility for remote access via the QR network provide through the use of “web enabled” software. New training features such as the provision of automatic expert driver, a fully configurable lesson option menu definable for a specific user or group of users and a graphical train building tool are discussed.

1. Introduction

QR has recently taken delivery of four 3000 class electric locomotive simulators and a 4000 class diesel locomotive simulator. The simulators were designed and built by Sydac Pty Ltd.

QR has for many years been at the forefront of simulator application for train driver training [2][4][6][7]. The new simulators include many features that QR has desired in a simulator that were not available in “off the shelf” train simulators. These features provide the drivers and the instructors with a simulator that can be used as a standard part of a driver’s education.

The features that separate the new simulators from other train simulators are outlined in the following sections.

2. Training Objectives

Sydac Pty Ltd in conjunction with QR has developed simulators that deliver competency-based training to drivers at various levels of proficiency. The simulators were design and built around training objectives that have been developed by QR [3][4]

The primary objectives of the training delivered by the equipment are:

- Development of safe driving practices in long, heavy trains
- Improvements in fuel efficiency
- Optimisation train dynamics to minimise maintenance cost.

In addition to these primary objectives, the simulators are capable of delivering training in the following.

- Familiarisation with operating procedures such as marshalling trains and setting up remote and trailing locomotives.
- Fault diagnosis and remedies.
- Basic maintenance functions such as changing hose bags.
- Operational procedures such as communications with controllers and compliance with signals and signs.

The simulators are intended to facilitate and encourage 24-hour solo use by trainee drivers. The training should provide immediate and on-going feedback to solo trainees about their performance in a way that directly relates to their task. This self-assessment is intended to encourage individual practice and self-improvement.
3. Project Features

3.1. Electric Locomotive – overview

In the mid 1980s QR purchased 2 electric locomotive simulators for training drivers on the correct use of the 3000 class electric locomotives. The simulators were designed and built by ACET Ltd in Perth. The state of computer technology at the time meant that specialised equipment had to be used to construct the simulators. The simulators were built around HP1000 computers with custom interface electronics to 3000 class electric locomotive driver consoles. The vision was provided by “Laser Disk” players. Each simulator was built with two separate driver consoles allowing two drivers to be trained by the one instructor.

Due to their age and use of specialised computing hardware, the simulators had become increasingly unreliable and unserviceable. An upgrade project was commenced on the simulators in the mid 1990s.

The first stage of the upgrade was to replace the laser disk vision system with a computer based vision. This task was done by GEMCO of Perth who had taken on the upkeep of the simulators from ACET. The new vision system was run on SGI O2 workstations with the many kilometres of track vision being stored on removable JAZ disk drives. This system greatly improved the reliability of the simulator vision but still required instructors to manually select the vision they needed for a simulation.

From the many years of experience with training aids such as simulators, Pat Wilson from QR had designed a number of innovations that would improve driver training and assessment [1][4]. These new ideas were to be included as part of the phase 2 upgrade of the simulators.

SYDAC Pty Ltd won the contract for the second phase of the simulator upgrade. This phase required each simulator to be split into two separate simulators, upgrade all the computing hardware (while keeping the new vision system) and to overhaul the instructors and drivers consoles. A number of other requirements such as trainee only access and remote administration were included in the requirements for the upgrade.

Detailed documentation on the original ACET simulators and GEMCO vision upgrade was not made available to SYDAC due to copyright. Because of this and the degree to which the system needed to be upgraded, SYDAC designed and built completely new simulators using only the SGI O2 hardware, vision files, track data and drivers console shell from the old simulators. This approach allowed the simulator software models as well as the user interfaces to be bought up to date.

One of the aims for the new simulators was to make sure that there was a straightforward hardware and software upgrade path available for future developments. For this reason the simulators were based around standard desktop PCs running Windows NT.

The vision system was rebuilt using the phase 1 upgraded hardware (SGI O2) but with the software rewritten so that the vision files were in industry standard “Quick Time” format. The Jaz disk system was also replaced with hard disks so that vision selection did not require the operator to change disks.

The first of the simulators was delivered to QR in mid 1999 and has been in continuous service since that time.

3.2. 4000 Class – overview

QR is acquiring from Clyde Engineering, a fleet of 38 new A/C traction diesel electric locomotives designated the 4000 Class. Sydac has developed a mobile simulator for the new locomotive under sub-contract to Clyde for delivery to QR.

The 4000 Class simulator is contained in a 13.7 metre pantechnicon trailer. QR will operate it initially at five sites around Queensland (Rockhampton, Callemondah, Jillalan, Pring and Stewart).

A modified 4000 Class cabin provides a realistic environment for the driver in terms of displays and controls.

A forward projected vision system provides visuals through the driver-side windscreen. Ten hours of filmed track vision is stored compressed on hard disk. It is correlated to a track database and played frame-by-frame as demanded by the simulation model.

An audio digital system driven from the simulation model and the track database, provides 3D simulated sound within the drivers cab to represent locomotive equipment sounds, and externally generated sounds such as crossings, bridges and cuttings.

Inside the driver’s cab there is a Train Performance Display (TPD) which gives the driver a number of graphical and textual displays that can be used to assess driving performance (eg in-train forces, brake pipe parameters).

![Simulator Architecture Schematic](image-url)

Figure 1 Simulator Architecture Schematic
An instructor station provides the means to control the training scenario and monitor the driver’s performance as well as all the cab equipment. The trailer features

- 24-hour access to trainees using swipe card
- a number of security monitoring features
- non-interruptible powers supplies
- climate control
- air bag chassis suspension

4. System Architecture

A common system architecture is used for both the 4000 and 3000 Class simulators. It is based on maximum use of commercial off the shelf (COTS) equipment.

The 3000 simulator had previously been built around custom circuitry. A design aim was to simplify future upgrades by requiring minimal or no changes to locomotive equipment.

Features of the simulator architecture include:

- Use of Windows NT work-stations for all compute nodes with the exception of vision and audio simulation.
- SGI processors for vision and simulated audio
- The design ensures that processor nodes are interchangeable – adding plug-in cards was actively avoided.
- Programmable logic controllers (PLCs) for interfacing to locomotive equipment and control of trailer systems.
- Single point (one pushbutton) to power on and power off the entire simulator without further user intervention.
- Use of web servers to simplify connection of nodes to system data sources.
- Custom built equipment has been avoided and confined to replicating locomotive equipment which was unavailable or for which interface information was not forthcoming.
- Dial-in and direct network connection from external sites for system management, remote monitoring and system maintenance.

The architecture is illustrated Figure 1.

5. Model

For simulators to be an effective training tool a good correlation between the real train performance and the simulator is necessary [6][7]. This is particularly important for train simulators where drivers are accustomed to the behaviour of a train in a controlled environment (fixed track). In addition to this the simulator is able to calculate quantities that the driver does not normally see. This ability to “see inside” the train provide the driver with a good understanding of how the train is behaving.

The model developed for the 3000 and 4000 simulators was based around SYDAC’s extensive experience in modelling train and brake system dynamics. The core of the models was developed from high fidelity (non real time) models of complete brake systems and train dynamics [8][9]. These models were originally designed to predict the behaviour of train dynamics under normal and abnormal conditions as an aid for engineering design. The models were built by simulating actual physical behaviour of the system without resorting to extensive empirical data. By simplifying the models SYDAC was able to produce an accurate model of the train and brake dynamics that still maintained its “physical” nature. This approach means that the operators at QR can modify the behaviour of the model by altering real train parameters such as wagon mass and brake system volumes.

Attached to the train and brake system dynamics model is an accurate simulation model of the locomotive and its functionality. This model includes simulation of the locomotive traction and braking systems, locomotive control logic and the distributed power systems.

By modelling the train down at the physical component level, the simulation model is able to reflect the behaviour of many of the train components that the driver does not normally have access to. The parameters include train tension and compression, brake system volume pressures and brake fade. This extra insight into the state of the train allows the trainee to learn how their actions affect the train. These effects can be correlated to the student’s actions and train behaviour allowing them to recognise the situations on real trains.
The final simulation model has been shown to be accurate when compared with measured train performance (Figure 2). Continuing tuning of the models against actual train behaviour in many different operating conditions is further enhancing the model accuracy.

6. Simulator Features

Both simulators include the expected features common to most simulators. These include:

- Facilities to set-up lesson scenarios (choose trains, tracks and so on) and monitor the trainee
- Injection of faults
- Recording and replay of lessons.
- Printed reports and graphs
- Definition and editing of loco and wagon characteristics
- Voice communications and role playing

Some features of the simulators are designed specifically to support QR’s training methods and the way in which QR wish to operate and maintain their equipment.

Some of these features are described in the following subsections.

6.1. Trainee-only and 24 hour access

Part of the QR training philosophy is to ensure that train drivers spend a minimum amount of time honing their skills on the simulators. To achieve this aim in a cost-effective manner it is necessary to have the simulators available for use by the drivers at any time of day. The other locomotive simulators operated by QR require an instructor to be on hand to “run” the driver training session. The new simulators are designed to allow any driver with the correct access to be able to simply power up and use the simulator without the need for them to be overseen.

To achieve this aim, the simulators were built with a swipe card access system. Each driver is issued with a swipe card that allows a particular level of access. When the operator swipes their card in the simulator, the simulator will automatically power up and display a pre-set list of scenarios for selection. The trainee can select one of the scenarios and start their training. On completion of the training the simulator automatically logs the session and, after a delay, powers down.

Logs are kept on who has accessed the simulator. These logs can be remotely accessed from a central location. This system gives QR the ability to include simulator training as part of drivers’ continuing development without the need to impose set times for training sessions.

6.1.1. Configurable lessons

Because of the policy of providing 24-hour solo access, it is essential that starting the simulator and selecting a lesson is made easy.

Once access is granted, a trainee is presented with a menu on a screen that lists five lesson choices – four train driving scenarios and one tutoring scenario. That menu can be tailored to a particular trainee.

Alternatively, trainees can be assigned to any number of named trainee groups. A menu is associated with each group and can be defined and modified by an instructor.

A trainee may run any of the lessons any number of times. When the trainee logs off the simulator, the results of the most recent driving session are saved automatically for analysis or assessment.

6.1.2. Tutoring (expert driver)

A feature referred to as tutoring enables an instructor to produce and save a ‘canned’ scenario to demonstrate to trainees how to drive a particular scenario.

An instructor selects and then drives a scenario. All control actions for the session are saved so that the simulator can repeat the instructor’s actions.

The instructor then replays the saved control actions. At desired times and places during the replay of run, the instructor can pause simulator while he/she enters spoken and written messages. These are then be played in the cabin or displayed in a screen in the drivers cab when the trainee plays the tutoring scenario.

Features permit offsetting messages in time or location and selectively pausing the simulator while messages are played.

6.1.3. Scoring and driver assessment

A key tool in the training of drivers is the ability to assess the drivers’ performance under a number of criteria. This is achieved by the use of driver scoring. The score is based on a set of driving rules that have been developed over the years to optimise energy consumption, in train forces, time and safety. By the introduction of a scoring method, which evaluates the total driving experience, objective data analysis is possible. Objective data enables the participants, (drivers) to make judgements about their performance and compare their outcomes with others.

The comparison of outcomes, either as a group, or independently, encourages discussion and ownership of the outcomes. Ownership generates practice in the work environment, which in turn, creates a learning environment and positive transfer of learning.

Positive transfer of training is defined as the degree to which trainees effectively apply the knowledge, skills, and attitudes gained in training context to the job.- Atkinson and Fleishman as quoted in [5].

The use of simulation data creates a self-motivated learning cycle, which, combined with the trainee only mode of operation (Section 6.1) assists to generate a learning culture that challenges participants to evaluate their practice, which in turn, assists in the positive transfer of training.
In addition to the driver scoring system, each simulator provides detailed reports on the simulation run. These are provided in an online format and in files compatible with QR’s driving assessment software, SIMSOFT.

6.1.4. Graphical train building

Both simulators described provide graphical methods to build trains to be used in training scenarios. Graphical interfaces are used to build new trains and modify existing ones.

A point-and-click interface enables trains with multiple consists to be readily built and modified. Consists can be readily redefined and moved within the train. Wagons are selected, loaded and added or removed to or from any point in the train, using wagon definitions stored in a database.

Train mass and mass distribution are prime factors to consider when building trains for teaching drivers. Mass distribution is shown graphically with indicators to show centre of mass for the entire train and individual rakes. Mass can be readily redistributed using point-and-click editing to focus on particular sections of the train.

6.1.5. Fault finding and procedural training

Elements of driver training require inspection and control of items of locomotive and train equipment not located in the cabin. These are often not represented in simulators.

A screen-based procedural trainer has been developed for the 4000 Class simulator to represent items located outside of the driver’s cabin that are needed to teach set-up and fault finding procedures. It allows the driver to ‘walk the train’ using a computer screen and pointer (mouse or track ball).

Items implemented through this station include, among other things:

- Circuit breaker panels
- Engine oil and water level indicators
- Individual wagon hose bags
- Remote locomotive cabin controls

This virtual equipment interacts with the locomotive model and train model. For example, to open or close a circuit breaker, the trainee need only point and click an image of the required breaker.

The station uses a hierarchical set of images that enable the trainee, by pointing and clicking, to navigate around the entire train and access the virtual equipment of interest.

The train presented on the station is built dynamically to exactly match the configuration and the initialisation states of the equipment being used in the particular training scenario. Images are modified as required to represent change of equipment status (e.g., circuit breakers open/closed).

6.1.6. Remote access

The new QR simulators have been designed to be used in remote locations throughout Queensland. The 3000 class simulators are located at the driver centres in Rockhampton, Callamondah (Gladstone) and Jilalan. The 4000 class simulator is mobile and can be located wherever required. The remote location of the simulators necessitated the development of method running the simulators from a single centralised location.

The simulators are each connected to the QR LAN/WAN. A central PC located in the Rockhampton training centre can connect into any selected simulator. The remote station can then perform a number of monitoring and control functions. These include,

- Configuring scenarios
- Starting scenarios
- Inject faults into a running session
- Building and defining train configurations
- Viewing reports on training sessions
- Monitoring a remote trainee’s performance

The remote access capability allows experienced instructors in the central training centre to instruct a novice at one of the remote simulators. The instructor has the same capabilities as if they were on site with the trainee.

Access to trainee only session reports that have been generated over the past four days are available through the remote link allowing the central training facility to monitor individual drivers use of the simulator.

This system greatly reduces the need for the expert simulator instructors to have to travel to the remote locations. This represents cost savings to QR while maintaining a high standard of training.

6.1.7. Remote maintenance

In addition to the remote simulator access described in Section 6.1.6, a remote maintenance system has been set up for the simulators. Each simulator has a modem that can be connected to the instructor’s station. The simulator developers can then dial in from a remote location to maintain all the computers in the system. The remote connection gives the maintenance engineers full access of the remote access (Section 6.1.6) as well as access to the system database and log files. Software upgrades for each computer in the simulator can be done over the remote link.

Using this system simulator problems can be quickly identified and rectified without the need to travel to the location of the simulator. Software upgrades can be done directly by the support engineers resulting in a superior level of maintenance support.

1 This mode is removable for security reasons
7. Conclusions

The new locomotive and train simulators built by Sydac Pty Ltd for QR provide a improved training environment. The simulators are built around standard PCs and operating systems to provide as cost-effective upgrade path. Web based technology has been employed to allow the simulators to be controlled and monitored over QR’s intranet. The simulators benefit from features such as trainee only operation, remote access, remote maintenance and procedural trainer.

The open architecture of the simulators ensures that they will provide many years of service to QR while allowing for continual development.

8. References


