Abstract

Optimisation of the transportation of export coal from the Mpumalanga coalfields to the Port of Richards Bay presents a number of challenges. The transport demand and the network availability is variable, the origins of the coal are spread over a large geographical area, while a complex mix of rail network, traction power supplies and rolling stock technologies need to be taken into account to optimise delivery. In addition to this, loading facilities vary from manual loading using front end loaders to automated rapid loaders each with different constraints regarding timing, rolling stock and the like.

The objective to maximise the volume that can be transported in this system is hampered by the number of permutations and the complexity of the set of constraints making the use of an automated system the only feasible option.

These variables and the solution provided are discussed in the paper and it is shown how an integrated planning, monitoring and re-planning system was developed, not only to improve customer service delivery and obtain a feasible and optimised train plan, but to recover from in-service deviations.

Introduction

Transnet Freight Rail owns and operates the Export Coal heavy haul rail corridor. The line was commissioned in 1977 and transported 4.2mt in its first year of operation. Since then the operation has grown to its current status of being a World Class Heavy Haul line moving record tonnages in excess of 69 million tons per annum (mtpa). In the more than 30 years since its inception, the line has developed, the number of mining customers has grown and
changed and the assets have gone through various life cycles. Over the past decade, investment in the corridor has focused on sustaining infrastructure and on expansion of the system. A key element of investment has been modernisation of assets. Whilst this investment programme is underway the system reflects a mix of modern and legacy assets contributing to significant complexity in operations and thus in optimising rail scheduling.

The task of scheduling a system such as the export coal line is an incredibly difficult task, owing to the rail network’s existing infrastructure and differing train restrictions on the northern and southern parts of the line as well as a complex scheduling environment. Challenges that influence scheduling include several operational constraints, a large number of decision variables pertaining to resource and slot selection, varying weekly demand, multiple objectives and an adverse execution environment that requires a dynamic schedule.

This paper describes the dynamic environment and the solution that was developed for the rail resourcing and scheduling challenge.

**The Heavy Haul Export Coal Line Rail System**

An understanding of the total rail operation in the supply chain that transports coal between 65 and 70mtpa to the coal terminal at the Port of Richards Bay is integral to an appreciation of the design objective, the nature and extent of the challenge and the ultimate solution and its performance results.

**Process Model**

The efficient movement of ~70mtpa of coal from approximately 50 coal mines and loading sites in the Mpumalanga coalfields, Natal mines and farther afield in the Lephalale area to the Port of Richards Bay, involves a number of elements in the operations process which may be likened to a conveyor belt type flow depicted in Figure 1.

At the simplest level, trains of 50 and 100 wagons are run to customers’ loading sites where they are loaded with coal. These loaded trains are then routed to the heavy haul line key operational depots where the wagons are combined into trains of 200 wagons in length. Once combined, rakes of 200 wagons are connected to powerful locomotives – operated in a consist of four to six locomotives per train and the journey to the Richards Bay terminal begins. Once offloaded at Richards Bay using a tippler system, trains of empty wagons are compiled and returned to operational depots in readiness for the next deployment.
The two major hubs in this operation are Ermelo and Vryheid. The Vryheid depot primarily serves the Natal mines and deploys 50 wagon trains in this area to customers’ sidings for loading. Loaded wagons on trainloads of 50 wagons are returned to Vryheid where they are combined with traffic emanating from Ermelo in the north into 200 wagon trains to be run to the Richards Bay Coal Terminal (RBCT) in Richards Bay. Vryheid is also an important operational depot for crew changes – a primary operational resource and thus a key variable in modelling and developing a resource and scheduling tool.

The larger and more critical depot is the Operational Depot at Ermelo – the focal point of the heavy haul operation. This marshalling yard consists of four sub-yards where rakes of 100 loaded wagons from the loading sites are combined into 200 wagon trains destined for RBCT and once returned from an empty leg, 200 wagon trains are split up into two sets of 100 wagons for next deployment to the loading sites. Crew changes also take place here, as do locomotive changes due to the change from AC to DC power at Ermelo. Both locomotives and wagons are inspected at this depot and those that require maintenance – “Not To Go” – are removed and taken to maintenance workshops. All of these activities require detailed planning and scheduling.

The final destination of a loaded export coal train is the Richards Bay Coal Terminal which is served by the adjacent TFR depot named “2279”. Not only are the 200 wagon trains split into 2 x 100 wagon trains that can be accommodated by the rail facilities at the terminal and offloaded by the tippler onto stockpiles in readiness for loading onto a shipping vessel, other rail operations processes are also carried out here. In addition to locomotive and crew changes and moving “Not To Go” rolling stock to relevant maintenance depots in the vicinity, trains of empty wagons are also re-consolidated into 200 wagon trains for the return journey to Ermelo or Vryheid or to en route loading points between Richards Bay and Ermelo such as Enqoloti and Panbult.

Each and every aspect of this process requires sophisticated scheduling to ensure that resource utilisation is optimised, dwell times are minimised and volume targets are reached. There are however additional variables that add to the complexity of this operation and which increase the scheduling challenge.

**Geography of the Rail System**

The export coal line stretches almost 1000 km from Lephalale in Limpopo, to the coal fields in Ogies, Witbank and Middelburg in the west to Carolina in the east, past Ermelo and Vryheid down to Richards Bay as well as covering mines in the Newcastle and Glencoe area.

The network north of Ermelo consists of DC and diesel lines, and AC south of Ermelo.

The gradients from the loading sites to Ermelo restrict the maximum loaded trains to 100 wagons, but south of Ermelo the prevailing downward gradient allows 200 loaded wagon trains to be hauled.

From Ermelo, the approximately 700km route to Richards Bay consists of two lines, one being primarily for the down direction and the other for the up or return leg. The difference between the gradients of the two lines permits loaded trains only to run on the “down” line.

The section between Ermelo and Richards Bay runs through Vryheid and on to Richards
Bay to the TFR terminal “2279” which serves RBCT.

Offloading at the terminal of RBCT is done utilising one of five tipplers from where the coal is either stockpiled or dispatched directly to a vessel using stacker / reclaimers. The same stacker / reclaimer facilities are also used to load vessels from the stockpiles.

**Rail Network**

The line or network and key operational depots were originally designed and built to specifications to accommodate long and heavy trains at 26 tons per axle. The line traverses mountainous countryside requiring tunnels and varying gradients between the hinterland and the coast. Table 1 summarises the current rail network specifications and attributes:

**Table 1: Current Rail network specification and attributes**

<table>
<thead>
<tr>
<th>Network section</th>
<th>Axle mass</th>
<th>Traction power</th>
<th>Single or double</th>
<th>Gradient</th>
<th>Train Control System</th>
<th>Number of Sites</th>
<th>Rapid or drop-off</th>
</tr>
</thead>
<tbody>
<tr>
<td>Richards Bay - Vryheid - Ermelo</td>
<td>26</td>
<td>E AC</td>
<td>D</td>
<td>Line 1: 1:100 Line 2: 1:66</td>
<td>Centralised Train Control CS90</td>
<td>3</td>
<td>Drop-off</td>
</tr>
<tr>
<td>Ermelo - Carolina</td>
<td>20</td>
<td>D</td>
<td>S</td>
<td>1:50</td>
<td>Track Warrant</td>
<td>6</td>
<td>Drop-off</td>
</tr>
<tr>
<td>Ermelo - Trichardt</td>
<td>26</td>
<td>D</td>
<td>S</td>
<td>1:80</td>
<td>Track Warrant</td>
<td>1</td>
<td>Rapid</td>
</tr>
<tr>
<td>Ermelo - Wonderfontein</td>
<td>26</td>
<td>E DC</td>
<td>S</td>
<td>1:100</td>
<td>Centralised Train Control CS90</td>
<td>6</td>
<td>DO and Rapid</td>
</tr>
<tr>
<td>Ermelo - Blackhill</td>
<td>26</td>
<td>E DC</td>
<td>D+26 ton 3rd line</td>
<td>1:100</td>
<td>Centralised Train Control CS90</td>
<td>20</td>
<td>DO and Rapid</td>
</tr>
<tr>
<td>Ermelo - Delmas</td>
<td>20</td>
<td>E DC</td>
<td>D</td>
<td>1:100</td>
<td>Centralised Train Control CS90</td>
<td>3</td>
<td>DO and Rapid</td>
</tr>
<tr>
<td>Ermelo - Grootegeluk</td>
<td>20</td>
<td>E DC, E AC</td>
<td>D</td>
<td>1:50</td>
<td>Centralised Train Control CS90</td>
<td>1</td>
<td>Rapid</td>
</tr>
<tr>
<td></td>
<td>Diesel</td>
<td>S</td>
<td></td>
<td></td>
<td>Track Warrant</td>
<td>1</td>
<td>Rapid</td>
</tr>
<tr>
<td>Ermelo - Uitkyk</td>
<td>20</td>
<td>E DC</td>
<td>S</td>
<td>1:50</td>
<td>Centralised Train Control CS90</td>
<td>3</td>
<td>Drop-off</td>
</tr>
<tr>
<td>Vryheid - Natal mines</td>
<td>20</td>
<td>D</td>
<td>S</td>
<td>1:50</td>
<td>Track Warrant</td>
<td>3</td>
<td>Drop-off</td>
</tr>
</tbody>
</table>

Most of the network has a 26 tons per axle grading allowing wagons with a maximum of 104 gross tons to traverse over these lines. On some of the sections, such as Ermelo to
Carolina, a 20 tons per axle grading allows wagons with only a maximum of 80 gross tons to be hauled. In these circumstances smaller wagon types are used with a capacity of 58 net tons or larger capacity wagons are partially loaded to the maximum permissible mass.

The majority of the rail network consists of double or triple lines. The section between Ermelo and Carolina and between Ermelo and Trichardt are however single non-electrified lines where diesel locomotives are used as the motive power.

The double line between Ermelo and Richards Bay is in fact two separate single lines whereby loaded trains can only move on the “down” line. These lines are signalled bidirectionally allowing trains to move in both directions on each of the lines. The complexity of this line is further intensified by the Overvaal tunnel south of Ermelo. The tunnel construction is such that it reduces the route to a single line and two points where the two lines cross at a level crossing. These constraints require that trains be evenly spaced to enable a constant flow and to limit trains (especially loaded trains) having to stop to allow oncoming trains to pass. Stopping trains of this mass and length causes significant delays and an increase in operating costs and are thus avoided as far as possible.

The electrified network is served by evenly spaced electrical sub-stations. There is a limit on the number of loaded trains that can be served by each sub-station again placing a further restriction on the running of trains and therefore a greater need for evenly spaced trains.

Traffic on the rail network is controlled by five centralised train control centres (CTCs) at Witbank, Ogies, Ermelo, Vryheid and the Port of Richards Bay. At these centres, train control officers route trains, set points and signals and monitor train movements to ensure the safe and efficient movement of trains.

**Product and Customers**

The Richards Bay Coal Terminal (RBCT) is a facility privately owned by ten shareholders. The size of the shareholding governs the capacity allocated to each shareholder at the terminal and thus the annual tonnage per shareholder. Transnet Freight Rail’s contractual obligation to the shareholders is aligned with this allocated capacity. Weekly demand management endeavours to maintain this ratio.

Close to 50 mines and loading sites are owned by this consortium from which the demand for transport will emanate. Due to a number of factors such as varying rates of production, weather conditions and rate of loading product at the mines, demand per loading place varies from week to week. This fact, linked to the variable resource availability and positioning, amongst other things requires the capability to dynamically schedule the service for which the use of a fixed schedule is impractical.

**Rail Assets and Technology**

Due to the difference in electricity feed, i.e. AC and DC as well as the non-electrified sections, three classes of locomotives are required for the operation. These locomotives are ring-fenced to this corridor due to the nature of the constraint. North of Ermelo on the DC portion of the network 10E electric locomotives and 37 Class diesel locomotives are used in consists of four locomotives capable of hauling 100 wagon trains of loaded wagons totalling 10 400 gross tons.
South of Ermelo, on the AC section, consists of 4x11E or 6x7E electric locomotives haul the 200 wagon trains which amount to 20 800 gross tons.

Since 2008 the dual voltage AC/DC 19E locomotives have been introduced and are used north and south of Ermelo. The power output of the 19E locomotives is equivalent to the 10E and 7E models and are thus used in consists of four north of Ermelo and six south of Ermelo.

Due to small configuration differences of, amongst others, the pantograph of the 19E, not all loading sites were capable of being served with these locomotives. This problem was eliminated through the adaptation of the overhead power feed system (OHTE), but for the interim period was a significant constraint which had to be taken into consideration in the scheduling of the weekly service.

Two types of rail wagons are used in this system – the high capacity “Jumbo” wagons capable of carrying 84 tons net and the lower capacity “Smalls” capable of carrying 58 tons. Both types of wagons have two wheel sets (bogies) of two axles each. The grading of the rail network and loading of either 26 or 20 tons per axle, govern the usage of these wagon types. Loading sites limited by either the rail capacity or the electrification impose a further constraint in the scheduling of the service. Should “Smalls” not be available to provide to lower capacity loading points, “Jumbos” may be provided which are then loaded with 60 tons of product only, to still remain within the capacity restriction. This has an obvious impact on the output of the system – not only due to the lower tonnage, but also due to the longer loading times typical of these loading sites which are mechanical type loaders.

Both wagon types are equipped with air brakes (as opposed to the much older and inefficient vacuum brake systems still in use in Freight Rail). The wagons’ brakes are applied by default when the system is not charged. To release the brakes and to enable wagons to be moved, the brake system is charged by air compressors on the locomotives which bring the pressure to the desired operating level. The pressure in the system is monitored and communicated to the train crew by an “end of train device” (or telemeter) at the back end of the train. Brakes are applied by releasing air from the charged system by way of the valve system on every wagon, which is controlled from the locomotives. Although being far more efficient than the vacuum system, there is still a time lapse in the application of brakes over the length of the train influencing train handling and stopping distance.

This time lapse has been eliminated by the introduction of an Electronically Controlled Pneumatic Braking System (ECP) that has been installed on the jumbo wagons. The activation of the brakes on all of the wagons is simultaneous by means of an electrical connection running the length of the train. This system is however incompatible with the normal air braking system which is a further constraint in the combination of loaded wagon sets at Ermelo destined for Richards Bay as well as the combination of north bound empty sets at “2279”. In order for ECP wagon sets to be handled, loading sites had to be adapted, especially where equipment owned by the customer is used to move trains. Both of these constraints have a significant impact on the scheduling of wagon sets and had to be included in the scheduling solution.

Loading sites are generally classified as “rapid loaders” or “mechanical loaders” based on the design of the loading equipment. The rapid loaders utilise a flask loading system which is charged with sufficient coal for an entire train. The load is then dumped in the wagons moving at constant speed underneath the loading chute located in a loading tower. The
locomotives remain on the train and are used to move the train through the loading site located on a looped railway line leading from the main line and back to the main line and so removing the need for shunting of wagons.

In contrast, the mechanical loaders consist of one or more lines adjacent to loading areas where coal is placed before the arrival of the train. Once wagons are placed on the loading area by way of shunting wagons (either by Freight Rail locomotives or by the customers’ own shunting locomotives), wagons are loaded by front-end loaders. At these loading sites, the locomotives typically do not wait for the loading to take place, but are removed and are either returned light to the hub, or are used to collect loads loaded in this fashion at other loading sites.

The loading times between loaders generally differ, although four hours is set as the minimum standard. Reclaiming time, i.e. time required to be ready for the next load is directly impacted by the source of coal, the setup of the loading site and method of loading. These timing differences and difference in operation method (dropping off locomotives or retaining them with the load) further complicates scheduling significantly and if not done efficiently reduces the capacity of the total system immensely.

**Rail Operation**

To attain the targeted volumes, there needs to be a constant and even flow of trains on the main line section between Ermelo and the Port of Richards Bay. Scheduling and managing the trains to limit peaks and valleys is imperative. To this end, 24 hourly time slots are available on this section for export coal. It has to be borne in mind that this corridor known as the coal line is also used to convey other general freight such as chemicals, timber, chrome and the like. These commodities are scheduled to be operated in between the export coal running to the RBCT.

Under normal circumstances, not all 24 of the slots are used; two out of three slots (i.e. 16 slots per day) are sufficient to attain the desired volume levels. The remaining slots are used to recover to schedule in the case of incidents and deviations. During these periods a higher tempo is run by utilising every slot. The scheduling system is set up accordingly; normal operations will leave the required gaps, but when rescheduling after deviations all slots will be utilised until normal levels are attained.

At the two important hubs, Ermelo and “2279” at RBCT, the major part of the process time is taken up by inspecting wagon sets, splitting or combining wagon sets and generating brake pressure after locomotives have been attached to the load for shunting in the yard and for running on the main line. This process requires the synchronisation of wagon, locomotive and crew cycles – each with different timing parameters.

Scheduling of crew is not seamlessly integrated yet and at this stage aims at crewing the available slots in a manner conforming to the agreed resting periods. Crew qualifications are temporal and often do not cover all combinations of equipment. This fact complicates crewing scheduling and is exacerbated by the fact that the time required for many portions of the route is very close to the maximum permissible crew working hours of 12 hours, so incidents negatively affect the working severely.

A conundrum is created by the fact that the higher the required throughput, the higher the infrastructure maintenance levels that are required but the less time is available for these
activities. Network maintenance is performed between trains as far as possible, but monthly 12 hour total occupations are given to allow more complex work to be done. Annually, the route is closed completely for periods, to allow in depth maintenance to be performed.

Emergency occupations will be undertaken immediately should there be a danger of a failure of the network such as a cracked rail (often invisible to the eye) or incidents of a failure such as broken rails that can cause derailments.

Scheduling must have the ability to take cognisance of planned down times in various parts of the network (both for Freight Rail and for customers) and allow for as many as possible movements around these impediments. In the case of emergency occupations due to failures or external factors such as theft or vandalism, the system must be able to provide the best possible alternative solution in the shortest space of time.

**Railway Scheduling**

Given the overview of the coal line network and the operations to move coal from various loading sites to RBCT at the Port of Richards Bay, it is clear that a fixed schedule (such as being used by passenger services in Europe) is impractical. Due to the complexity emanating from the large number of factors and variables, it is also clear that manual scheduling will be highly ineffective and the time required for such a solution far exceeds the time available in a 24x7 operating model. Should it be assumed that a manual system is possible, the time and effort required to adapt the system in the event of variances and deviations, will far exceed human capabilities.

An alternative approach of “making the call as it happens”, namely scheduling for the moment after assessing the position and availability of resources, outstanding demand, crew availability, network availability and the like using expert knowledge, experience and corporate memory may seem viable and the network operators may be tempted to “do what we always do”. The reality is that since there are such a large number of loading sites, each with widely varying timing parameters and targeted volumes – not only for the typical operational period of the week but also for annual contracts, the number of options number in billions, thus become far more than the human mind can comprehend and process. The expert operational planner may be able to anticipate some future effects and outcomes, but the reality is that the negative effect of a sub-optimal decision is only experienced 24 or 48 hours into the future.

Scheduling at this level of complexity, to attain the maximum volumes with the least number of resources whilst adhering to all operational rules imposed from a safety point of view, hard constraints and contractual demands thus require highly advanced systems making use of scientific scheduling principles.

Transnet Freight Rail has thus progressed from manual and semi-manual prototypes to a comprehensive scheduling system that can provide a feasible and optimised solution, monitor actual movements against plan and has the capability of re-scheduling in the case of deviations to provide an alternative plan as close as possible to the original whilst always maximising tonnage throughput by minimising total delay in the system.

**Fundamentals.**

A basic and fundamental premise in planning and scheduling is that the plan or schedule
that is provided must be a feasible solution that can be executed under normal circumstances. If this premise is not adhered to, the operators who must execute the plan become despondent and revert to short term fixes and alterations which nullify the original effort and subsequent product. These fixes are typically uncoordinated, may be hasty and could be done by personnel not qualified or suited to this task.

The principal of scheduling is thus outlined by the following:

- **Model the operations** as accurately and in as much detail as possible. This step requires an in depth analysis which often leads to the spin-off of identifying sub-optimal or inconsistent practices at the outset which can be corrected with a view to the future solution and will provide positive results immediately.

- **Determine the drivers.** It is essential that agreement is reached as to what the drivers should be in creating the schedule. These include maximising volumes by minimising delays and waiting time in order to resolve all demand, as is the case for coal exports through RBCT, or it may be minimising cost, usage of resources, etc.

- **Agree on practical operating parameters.** These parameters include capacities and capabilities of locations, such as yard and loading site capacities, timing parameters such as processing times and forced idle times, running times between locations, available slots, dependencies and incompatibilities. Optimism is a common fault which must be tempered with attained results during operations which are more than likely less efficient than the ideal state due to congestion and real world impacts. For this reason the prudent approach is to select the operating parameters such that they represent most of normal operations and will lead to a workable or feasible solution. It is then incumbent on the organisation to focus on the constant improvement of these parameters through process improvement initiatives such as LEAN Six Sigma

- **Confirm demand.** The demand, in this case the volume required to be moved specified per loading site, is a critical input into the schedule. The production of stated volumes must be attainable under normal circumstances.

- **Confirm the availability of resources.** These resources include locomotives, wagons and the network.

- **Review the schedule.** Once a schedule is provided according to the model and the agreed parameters it is confirmed by a multi-disciplinary group of role players, the most important being the operators, crew management, the resources owners and commercial department focusing on the customer aspects. Should the schedule found to be lacking, the cause is then identified and adjusted. The iterative review then takes place until consensus is achieved.

- **Work according to the plan.** Two aspects are critical:
  
  - The run up towards the start of the operating period – since the schedule is typically produced 3-4 days in advance, micro adjustments need to be made so that the take up of the plan can be attained.
  
  - Following the plan as prescribed, especially as far as the order of the placements is concerned. This is critical due to the fact that the return legs of each loading site will arrive at different times and these arrivals are synchronised for the best result. The schedule is made robust by the spreading of loads over the scheduling period which allows for smaller time deviations.

- **Review the plan during the period of execution.** Regular pro-active reviews and countdowns to ensure that the plan for the subsequent period (typically 6 hours) can be executed. These reviews are performed with the relevant role players: operations, crew management, resources owners and commercial representatives to identify any items that would cause a deviation in the plan. Unplanned deviations due to external factors that may
occur, for example, equipment failures, adverse weather conditions, are handled in the same manner but with greater urgency. Should it become clear that the plan has become infeasible, the necessary adjustments are made to the inputs and a revised plan is produced, agreed to and then executed by operational employees.

- **Measure.** Critical measures are reviewed during execution, i.e. adherence levels to the schedule percentage loaded vs. unloaded wagons in the system (an early indication of imbalance) and the like to determine if the plan has been significantly deviated from to warrant a revised plan. Measures not supporting the level of adherence to execution are counterproductive and confusing and should not be used as they could lead to deviations being performed in order to conform to the alternative measure.

- **Adjust.** Following the approach of “plan, do, review”, regular reviews take place to identify slack in the system or in the scheduling. These are adjusted, agreed to and applied and thereby adjust the efficiency of the system continuously.

### Scheduling Tool

PLATO.Rail is the bespoke scheduling tool implemented in Transnet Freight Rail that caters for the needs of the coal export operation to RBCT. [PLATO is an acronym for Primary Logistics and Transport Optimizer]

**Procurement Approach.**

Transnet Freight Rail launched an international tender during 2010 for the scheduling of the coal export flows through the Richards Bay Coal Terminal at the Port of Richards Bay. Seven companies responded to the tender and after adjudication, OPSI Systems, a local company specialising in routing and scheduling systems was awarded the contract. The company’s expertise and proven track record around the highly successful routing and monitoring of the complex system of road vehicles between depots and retail points was applied to solve the rail problem.

**PLATO.Rail: Overview of the system.**

PLATO.Rail mimics the operating model of the coal export flows through RBCT to a great degree of accuracy. This is essential in attaining feasibility of the plan, i.e. producing a schedule which the operators will accept and be able to execute.

PLATO.Rail functions in two modes: (a) planning mode and (b) execution mode

- **Planning Mode**
  - Provide long term, mostly static, details such as operating parameters – running times, loading times, routing details, resource types permissible, compatibilities, incompatibilities and the like. These aspects are constantly reviewed as they have a fundamental impact on the outcome of the plan.
  - Tactical mode; the weekly creation of the plan extension for the following 7 days.

- **Execution Mode**
  - During the week of execution the system monitors the execution of the plan by minimal user inputs and feeds from Freight Rail centralised train control (CTC) systems and wayside readers that monitor train movements.
  - In this mode the capability exists to adjust for reality in terms of variances in demand or for deviations and incidents.
It is noteworthy that a single continuous plan exists for the coal export line through RBCT. Every weekly planning period an integrated extension is made to the existing plan. It is not a number of segregated weekly plans.

**Input, Output and Algorithm**

PLATO.Rail requires details of the following to create a plan

- Operating parameters, including production details of loading sites
- Demand – the number of loads per loading site that must be scheduled for
- Resource availability – the number of locomotives, wagons, network availability and loading site and off-loading site availability

These inputs are utilised to provide the schedule which conforms to all of the rules set. Should there be anything that inhibits the system from providing a feasible plan, such as fewer resources than required or other restrictions, the planning process is aborted. Conformance will however provide a plan that is evenly spread over the week with bias to the maximum capacity on the first 6 days of the week.

The result is a complete train schedule of all the movements that must take place between the hubs (Ermelo and Vryheid) to loading sites and from the hubs to RBCT, the end destination. Details include the prescribed splitting and combination of trains with scheduled times as per the slots made available and locomotive movements required especially in the case of drop-off loads. This period’s plan is integrated with the previous period’s plan to form a continuous plan.

The outputs are viewed in many different ways:

- A complete train diagram of all movements – for the trained eye this seemingly impossible detail of more than 220 trains in a week is a valuable source of checking balance and spacing
- Details per loading site – a “loading diary” for each of the loading sites

![Diagram of a complete train schedule](image-url)
• Order of execution – a simplified control list of the order in which loads must be dispatched
• Graphical web view of the aggregated plan by day and the status (planned, dispatched, loading, en route, complete, cancelled, etc.)
• Graphical view of each loading site vs. time – planned loads, revised plans and executed loads
• Train position snapshot – a schematic view of the total system indicating the relative position of trains between nodes, indication of adherence to the scheduled time and the number of resources at the hubs
• The plan expressed in text biased towards different users
• Management reports and statistics – a wide range of reports and statistics

The core of the PLATO.Rail logic revolves around the use of the genetic algorithm. The genetic algorithm not only finds feasible solutions but also selects an optimised solution. In the field of artificial intelligence in computer science, a genetic algorithm (GA) is a search heuristic that mimics the process of natural evolution. This heuristic (also sometimes called a meta-heuristic) is routinely used to generate useful solutions to optimization and search problems.

The genetic algorithm uses “a survival of the fittest” paradigm to generate an optimised solution in a relatively short space of time. The application essentially generates solutions and then fine-tunes them through successive generations subtly modifying previous solutions and crossing alternate solutions through some 200 generations to arrive at an optimised solution.

This algorithm succeeds in finding feasible and optimised solutions in an extreme space of time. Disregarding preparation for input and other administrative functions required to prepare the system, a workable solution is provided in ten minutes or less. Optimisation is improved by allowing additional solutions to be determined with a good level reached within 30 minutes.

Related solutions

The software engineering team considered the concept of a routing and scheduling system previously created in which the complex problem of determining road vehicles’ movements between depots and retail points was solved and implemented. PLATO.Rail was then created.
Many scheduling systems exist in the rail environment, but none were found to be ideally suited to the specific model of the coal line exports operation and its particular set of limitations and constraints.

Operational use of PLATO.Rail

The scheduling cycle for the coal exports through RBCT:
- Aggregated demand is received from RBCT based on stock availability and previous performance levels
- The demand is reviewed and agreed to by TFR commercial
- The scheduler is prepared
- The scheduling takes place
- The schedule is reviewed and once accepted, is published by the Friday for the next week’s operation

During the week of operation, the plan is constantly reviewed and if deviations of significant impact have taken place, a revised plan is created, reviewed and published.

Plato Rail Performance

Following the go-live of the PLATO.Rail system in March 2011, Transnet began to achieve record volumes of coal month-on-month as highlighted by South African business and industry media and confirmed by data released by RBCT. Transnet audited and confirmed delivery of 67.7 mtpa of export coal for the 2012 financial year – an 8.8% increase on the previous year.

The results are made more exceptional by knowing the challenges that Transnet Freight Rail had faced during the first half of 2011. A derailment occurred in March 2011 which closed two lines linking RBCT and Ermelo and a 20 day shut-down of the line in May-June for annual track maintenance.

A study regarding wagon cycle times for the Ermelo region – the time spent from being loaded to being offloaded – compared the month of October 2010 to October 2011. It was found that despite an increase of wagons on the network which resulted in more trips and cycles being performed, there was a decrease of 3% in wagon cycle time.

Schedule planning time was also reduced significantly to a fraction of the original time – the generation of schedules, both new and in reaction to occupations on the network, has been reduced from two days to an hour on average.

Transnet Freight Rail and OPSI Systems were awarded a Gold award in the prestigious Logistics Achievers Award in recognition of this ground breaking achievement in South African rail.

Conclusion / Future Applications

The system brought about a new way of working which is impacting processes and procedures of long standing. Due to the nature of the system there is no place for grey areas and non-defined operations.

Many positive changes have been brought about by the thinking behind the system and the
application of the system in Freight Rail.

Applications of this type of system in other environments have taken extended periods to establish and embed and the same trend has been experienced in Freight Rail. Further improvement of the rigour of constant planning as a continuous activity is underway.

The principle of a single feasible and optimised plan has been accepted in Freight Rail operations. This is based on the fact that an extension of PLATO.Rail to cater not only for export coal through RBCT has been authorised. The necessity of this expansion lies in the commonality of the loading sites to both RBCT and non-RBCT traffic which is impossible to cater for using independent, separately planned schedules. This extended version has been completed and is being implemented in the general freight environment on a flow by flow basis.

Recognising the methodology and supporting process used on the coal line as the direction of modernisation, Transnet Freight Rail is in the process of revamping the total planning process along these lines from long term service design to tactical planning and re-planning.

**GLOSSARY**

1. **CS90** – The traffic control system used by Centralised Train Control for the safe authorisation, routing and monitoring of trains. Although not the primary purpose of the system, an accurate positional and movement detail of trains on the network is available from the system.

2. **Track Warrant** – a radio based train authorisation system especially for single line lower density lines. This system is utilised to ensure safe passage of trains along the route under this method of train authority.

3. **Wayside readers** – electronic readers installed next to the railway line capable of detecting details of the train consist by way of the electronic radio frequency identification tags (RFID tags) installed on all locomotives and wagons. The exact location of wayside readers is known.

4. **Global Positioning System (GPS)** – satellite tracking units able to determine exact positional information, speed and direction of travel. Such units are fitted to locomotives enabling the tracking of locomotives (and known train consist).

5. **Integration of CS90, wayside readers and GPS information** – Each of these sources of information of trains and train movements may be lacking and incomplete, but by integrating the 2 sources of positional information (CS90 readings and GPS readings) and the train details gleaned from wayside readers, complete and accurate positional information becomes available for accurate train position monitoring that is independent on human input.

**Biographies**

**Hendrik Adriaan (Hennie) Muller**

Hennie currently holds the position of Executive Manager, Organisational Development & Performance in Transnet Freight Rail Operations. He holds Bachelor of Commerce and Honours degrees in Transport Economics obtained from the University of Johannesburg (formerly Randse Afrikaanse Universiteit). Hennie is a member of the Chartered Institute of Transport and Logistics. He has extensive experience in rail operations, systems,
measurement and information technology in the rail and transport environment. He is particularly skilled at conveying complex operational issues in simple terms which has earned him the reputation of an expert coach and leader in his field within the organisation.

**Deon van Niekerk**

Deon holds the position of Senior Manager, Organisational Development & Performance in Transnet Freight Rail Operations. He holds an Honours degree in Computer Science obtained from the Rand Afrikaans University. For most of his career in the rail industry he was establishing and supporting IT systems and processes for operations and so has gained an in depth knowledge of the core rail business. His work on the coal line culminated in the development and implementation of a ground breaking rail scheduling system. He has a keen interest and skill in data analysis from which efficiency improvement initiatives are driven.

**Sandra Gertenbach**

Sandra currently holds the position of Executive Manager, Strategy & Business Planning in Transnet Freight Rail (TFR). Her interest is in communicating plans, operations models and direction of the organisation to all levels of the organisation. She has extensive experience in strategy development and implementation, strategic marketing, research and has operational experience in a leadership role. She has extensive knowledge of the South African transport industry and the strategic issues of the freight and rail industries.

She holds a Master of Business Leadership degree and a Bachelor of Arts degree both from the University of South Africa.