Planning and design of Sentrarand Marshalling Yard

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Synopsis
This paper deals with the parameters which influenced the choice of a suitable site for a central yard. The definitions of the various components which form the complex and the civil parameters used to design these are provided. The reasons for constructing dedicated goods lines for access to the yard are outlined as are the technical aspects of these lines. Finally, the normal movements of trains through the yard are given.

Opromonking
Hierdie verhandeling handel oor die faktore wat de kaese van 'n gesikte persoon vir die sentrale terrein beïnvloed het. Die definisies van die verskillende komponente waardeur die kompleks gevorm word, en die stiviele parameters wat gebruik is in die ontwerp daarvan, word versal. Die redes vir die bou van spoorlyn wat net goedere verkeer na die terrein hanteer, word omkry, asook die tegniese aspekte van hierdie spoorlyn. Ten slotte word die normale beweging van treine deur die terrein bespreek.

Introduction
The planning of the new marshalling yard to serve the Reef area was done departmentally except for the aerial photography. A contract was concluded for this as the danger existed that large scale investigations by the SA Transport Services staff in a specific area might be observed and could have led to land speculation. Aerial surveying ensured that planning could proceed to the stage where land negotiations could be initiated without SATS staff having to set foot on the area selected.

Early in the planning stage it became reasonably obvious that three marshalling yards each with 64 primary sorting tracks and each with its own arrival, secondary sorting and departure yards would suffice until well into the next century. It was decided, however, that sufficient land should be reserved for a fourth module in case growth in excess of that estimated should take place. Based on these requirements an area approximately 11 km by 5.5 km, ie 6 000 ha, in extent was necessary for the project.

Selection of a suitable site
The various points that had to be borne in mind when selecting a site for a central marshalling yard in the Reef area were:
1. The approximate size of the tract of land required was 11 km by 5.5 km.
2. The natural slope of the area was to be as close as possible to the average slope required for the yard.
3. Dolomite can cause settlement and sinkhole problems.
4. As Germiston can be regarded as the centre of gravity of the flow of traffic in the Reef area it was necessary to site the new yard as close as possible to this point.
5. To ensure that exorbitant land prices would not have to be paid particular attention had to be given to actual and potential township development.

Various sites were investigated and after careful deliberation Bapsfontein was found to be the most suitable from all aspects. It had the added advantage of being suitably sited to handle Pretoria traffic as well as that for the Reef area. (See Fig 1.)

To ensure that other possible developments in that area would not be adversely affected, the project was fully discussed with members of the then Department of Planning who had no objections to the proposed site. The necessary land at Bapsfontein was expropriated in June 1973 at a cost of approximately R7 million.

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Planning aspects to be considered
One of the features of modern marshalling yards is that they are built with a hump between the arrival and sorting tracks. The yards fall into three main categories:
1. Prediction yards where either clap retarders (fixed equipment — this is a feature of the yards at Kaserne and Bloemfontein) or mobile retarders are used. With this type of yard the aim is to reduce the speed of a moving wagon so that it still has enough energy to reach the preceding wagon but without so much surplus energy as to cause damage to the wagons and their contents on impact.
2. Yards where the entry speed of the wagon into the sorting roads is controlled to within a specified range whereafter the speed is reduced to below buffing speed and the wagons are then pushed forward at buffing speed by specially designed wagon handling equipment.
3. Yards such as at Tinsley in Britain where fast moving wagons are retarded and slow movers are boosted to ensure that all wagons will move forward at a desired speed no matter what their rolling characteristics may be or what external forces may arise due to such factors as wind, temperature and curve resistance.

For clarity, for the remainder of this paper, ‘yard’ will be used to describe a collection of tracks which serve a common purpose, eg arrival yard, sorting yard, departure yard, etc., ‘module’ to describe a linked arrival yard, sorting yard, secondary sorting yards and departure yards, and ‘complex’ to describe the complete project.

To permit the planning of a module to proceed, certain tests had to be carried out to determine rolling resistances and coupling speeds.

Rolling resistance tests
A programme to measure the rolling resistance of as large a sample as possible of the SATS fleet of wagons was initiated. The results of the tests proved that the rolling resistances of the SATS wagons vary from 10N/t to 200N/t, i.e the best runners will maintain their speed on a grade.

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of 1 in 1 000 whereas the worst runners will only maintain their speed on a grade of 1 in 50. The average rolling resistance was found to be 100N/t equivalent to a grade of 1 in 100. The rolling resistance of 90 per cent of the wagons tested fell within the range of 70 to 170N/t and 99,2 per cent within the range of 40 to 180N/t.

It should be noted firstly that the rolling resistance of a wagon can be altered temporarily by a gust of wind or a track irregularity, secondly that the resistance is usually less when the wagon is loaded and, thirdly, that while the average roller bearing wagon has a lower rolling resistance than one with sleeve bearings the extremes do not vary much.

It was decided that the yard would be designed to handle wagons with a maximum rolling resistance of 180N/t in view of the small percentage in excess of this figure. Arrangements have been made to divert the balance of wagons before they reach the sorting yard turnouts.

Suitable speeds for automatic couplers

The automatic coupler aspect had to be clarified before a decision could be taken regarding the type of yard to be built. Fortunately the tests carried out in this regard proved that at a speed of between 1,0 and 1,5 m/s, which is an acceptable coupling speed range, the performance of the automatic couplers was satisfactory.

Decision regarding type of module to be built

As a result of the various tests it was decided to adopt a plan employing both retarders and boosters which would ensure that wagon speed would be fully controlled throughout the operation.

The Sentrarand complex was initially planned to consist of:

1. Four modules eventually.
2. Peripheral tracks around the modules to provide the connection between the modules and the new lines (hereinafter referred to as link lines and shown in Figure 1) which would serve the complex.
3. Separate block load yard(s).
4. The various workshops, locomotive sheds and other facilities necessary for the smooth functioning of the complex.

A master plan embracing these features was prepared (Fig 2). One module, two temporary blockload yards and various repair and maintenance depots have been provided initially. Future modules, additions and extensions will conform to the guidelines set out on the master plan.

Design of module

Briefly, some of the features taken into account were:

1. When considering the requirements for the new yard it was decided to provide for 200-axle vacuum-braked trains as the possibility exists that technical improvements can lead to trains of that length being introduced. This length was used for the arrival, main sorting and departure yards as well as for the shunting legs.
2. Occupation diagrams were prepared to determine how many tracks would be necessary in the arrival and departure yards; these were calculated to be 20 and 32 respectively. The latter figure may appear to be excessive but this is due to the fact that it was necessary to provide a sponge between the complex and the existing rail network as only some of the ultimate number of link lines have been provided as part of the first phase.
3. The 20 tracks in the arrival yard have been divided into four groups each with five tracks to avoid conflicting movements between the arrival and humping functions. This is effected by having two groups for arrivals and two for humping at any given time. Adequate escape tracks for main line locomotives detached in the arrival yard are provided.
4. Two sets of locomotives will perform the humping function. To avoid loss of time two tracks leading to the hump are provided. While one set of locomotives is humping a train, the other set of locomotives proceeds to the next train to be humped, couples up.
and pushes the load up to just short of the hump. It can start humping immediately after the first set of locomotives has completed its humping task.

5. To ensure that sufficient separation is achieved between a bad running wagon and a good running wagon destined for adjacent tracks in the sorting yard it is necessary that the distance from crest of hump to the 64 tracks which comprise the sorting yard should be as short as possible. To fulfill this design requirement the use is made of:

(a) One-in-six equal split turnouts, each turnout being preceded by a 6 m minimum length of straight track.
(b) Minimum radius of 150 m in respect of horizontal curves.
(c) The shortest physical length in respect of vertical curves on the hump. The rate of change used in the parabolic vertical curves is 1 m / 20 m / 20 m which is equivalent to 400 m radius circular curves. The hump at Kaserne marshalling yard was modified to this standard and no problems with wagons or locomotives have been experienced.

6. Special bypass tracks have been provided on each side of the sorting yard for wagons that cannot negotiate the hump or traffic that is not permitted to be humped.

7. Special groups of tracks have been provided at the far end of the sorting yard for:

(a) Staging the wagons mentioned in point 6.
(b) The cleaning of guards vans.
(c) The feeding and watering of livestock.
(d) Transferring traffic from one control zone to another.

8. To permit more efficient shunting at the exit end of the sorting yard the number of departure tracks was equally divided on either side of the sorting yard (Fig 3).

9. To satisfy the requirements that trains operating over main line sections (the Reef and Pretoria complexes and the link lines — see Fig 1 — excluded) be composed in specific format, provision has had to be made for two secondary sorting yards for traffic which cannot be sorted initially in the main sorting yard in that fashion. The secondary sorting yards are each equipped with humps, are designed in herringbone format and for the same reason as in point 8 above are placed on either side of the shunting lines serving the exit end of the sorting yard. Each secondary sorting yard (Fig 4) has five tracks of which:

(a) The centre track is used as the through track to serve 10 pockets, each of which will contain traffic for one destination only.
(b) The two tracks adjacent to (a) are each divided into five pockets which can each accommodate 16 axles (equivalent to four bogie wagons).
(c) The two outer tracks are used for two-way sorting or for overflow purposes.

Wagons are held in position on (b) and (c) by weight-responsive clasp retarders.

10. The function of making up trains in the departure yards has been completely divorced from trains departing from the two departure yards, thus eliminating any possibility of conflicting movements.

11. A depot (Fig 3) for the purpose of trip inspection and fault finding of main line electric locomotives is situated adjacent to the arrival yard and connected in such a way as to permit direct access to it, firstly from any pocket in the arrival yard and, secondly, the two departure yards without conflicting with any other yard movements.

12. Gathering roads in the various yards which fall fully within those areas where the operations are purely 'yard' functions have been designed as compactly as possible to minimize the time taken to perform the shunting operations.

13. Flexibility, where feasible and under controlled conditions, has been considered to permit more than one operation in a particular yard or portion of a yard to be carried out without the two or more operations affecting each other.

14. Adequate track centres were allowed in yards to accommodate:

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Fig 2: Master plan for the lay-out of Sentrarand
(a) Roads for motor vehicles used for carriage and wagon examination and repair, and maintenance of equipment and permanent way.
(b) Masts for electrification, high mast lights, signals, etc.
(c) Drainage, sewers, water supply pipelines, fire hydrants and roads.
(d) Cables.

15. Turnouts were provided as follows:

(a) Where the train operation can be classified as 'main line' or 'semi-main line': 1 in 12 and 1 in 9 turnouts.
(b) Where the train operation can be classified as purely a 'yard' function: 1 in 8 and 1 in 6 equal split turnouts

16. As the module comprises various yards, conflicting movements are inevitable. Provision has been made in the layout of the module to limit points of conflict to a minimum by introducing specific zones of control. This aspect is explained in the paper titled 'Signalling and operating systems of Sentrarand Marshalling Yard'.

Grading of module

The following considerations were taken into account in respect of the grading over the length of a module (Fig 5):

1. Arrival yard: This must be on a grade not steeper than 1 in 800 up or down. This is the steepest grade on which it is permitted to stage wagons equipped with roller bearings without having to apply the hand-brakes.
2. The tracks leading to the crest of the hump: An up grade of 1 in 40 is provided to ensure the bunching of the wagons to make uncoupling of the automatic couplers easier.
3. The crest of the hump to the beginning of the switching area: theoretically this section is on a 1 in 16 down grade to ensure that even a wagon with a high rolling resistance can open up a gap ahead of the following wagon to make certain that there will be no difficulty in achieving sufficient separation between the wagons at the point where they are switched onto separate sorting tracks.

As the vertical curve at the crest of the hump cannot physically be sharpened beyond the rate of change already mentioned, mechanical

![Fig 3: Marshalling yard (module)](image)

![Fig 4: Secondary sorting area](image)

![Fig 4: Detail of secondary sorting yard](image)
booster equipment (dealt with in the paper titled 'Mechanical Engineering involvement' is positioned at the hump to ensure the desired separation. In practice the vertical curve over the hump joins up with the vertical curve which terminates at the start of the switching area.

4. The switching area: A grade of 1 in 40 is necessary in this area to ensure that all wagons maintain their speed through the turnouts and curves, the faster runners being slowed down to the desired speed by retarders. The grade of 1 in 40 (250N/m) makes provision not only for the rolling resistance of a bad runner (180N/m) but also for any resistance it may experience due to turnouts, curves, idling resistance of the retarders, wind, etc.

5. Main sorting yard: Theoretically the grade in this area should be roughly that on which the wagon with the average rolling resistance will maintain its speed. However as the average rolling resistance of the SATS fleet of wagons is likely to improve due to increased use of roller instead of sleeve bearings, it was decided to design for a grade of 1 in 250. This means that more boosting equipment will be necessary initially but that as the average rolling resistance improves so this additional equipment can be reduced.

6. Far end of main sorting yard: This portion is on an up grade of 1 in 40 to ensure that all wagons whether good or bad runners are brought to a stop before being allowed to foul the turnouts at the exit end of the main sorting yard. Furthermore the length of this up grade is such as will give an average grade over the whole length of the main sorting yard not steeper than 1 in 800 down.

7. Secondary sorting yards: These two yards, where the flow of traffic is in the reverse direction to that in the main sorting yard, have similar grades to those given in points 2, 3, 5 and 6 above except that the 1 in 250 grade in (5) for wagons with an average rolling resistance is altered to 1 in 133. This steeper grade assisted by booster and retarder equipment is necessary to ensure that the gap between two consecutive wagons will be adequate to permit of switching at the greater distance to the furthest turnout that wagons have to travel. The latter grade was calculated by making an economic assessment of steep grade and purely retarder equipment on the one hand and a flatter grade and a combination of both booster and retarder on the other.

8. Departure yards: As for the arrival yard the grade in the departure yards must not be steeper than 1 in 800.

Services
To ensure the smooth functioning of the complex the design encompasses:

1. A water supply and reticulation system. Water is obtained from a Rand Water Board main which necessitated laying 15 km of 225 mm diameter pipeline from the connection to the reservoir in the complex. This pipeline can provide a maximum of 2 000 m³/d.
2. A comprehensive drainage system in the module and in all service depots being provided.
3. A sewage disposal plant. The purified effluent will in the main be used to supply a horticultural depot which is still to be provided in the complex.
4. A steam generating plant for supplying steam for various workshops and for the comfort heating of staff.
5. Maintenance, repair and servicing depots for electric locomotives, diesel locomotives, wagons, road vehicles, mechanical equipment, electrical equipment, signals and telecommunication equipment, and buildings and permanent way, as well as stores handling facilities to serve these depots.
6. A hostel complex for labourers embracing three dormitory blocks each catering for 400 persons (ultimately five blocks), dining and recreation halls, a modern stadium and other sport facilities.

Personnel
The introduction of Sentraran and resulted in staff being required for the handling, examination and servicing of trains and for the maintenance of equipment, permanent way and rolling stock. Despite these staff needs this project will result in an overall saving of staff on the Western Transvaal System and probably also on the adjoining systems.

The link lines to the complex
The salient feature that had to be observed when planning the link lines was that the complex had to be served with a constant and steady flow of traffic for 24 hours a day and could not be subjected to influences that would affect the planned throughput of the modules.

The flow of goods traffic on the present railway network in the Reef and Pretoria areas — and the signs are becoming apparent in the Vereeniging area — is adversely affected by morning and evening suburban passenger peaks and for this reason the existing lines carrying suburban passenger traffic had to be by-passed.

A problem that was experienced with the location of the various link lines was the presence of numerous residential and industrial townships. Not only did large numbers of these townships already exist but additional ones were continually being established. In a period of six years nearly 1 000 applications for the proclamation of new townships in the Reef area were submitted to the relevant Provincial authority. Therefore, although certain of the link lines are unlikely to be built for

Fig 5: Longitudinal section of hump and main sorting yard (84 tracks)

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some considerable time, it was considered advisable to expropriate the necessary land at an early date. Parliamentary authority to proceed with the expropriation of the land required for all the link lines was thus obtained.

The following design features were taken into account:

1. Traffic projections made by the statistical section of SATS were used in calculating track capacity and hence the ultimate number of tracks which had to be planned for in respect of each link line. The design of each line is thus based on ultimate requirements with only certain portions being provided initially.

2. The lines are regarded purely as 'through' lines to the complex and do not normally require crossing or passing facilities for trains. However, cross-over facilities at acceptable distances based on running times obtained from computer train simulation programmes are being provided for maintenance purposes. It follows that no commercial facilities in the form of goods facilities and stations, will be available to the public on the link lines as such facilities are available on existing lines.

3. The link lines will handle not only traffic destined for the complex but will also accommodate blockload goods traffic passing through the Pretoria-Witwatersrand-Vereeninging area. As the tendency on modern railway systems is to operate longer and heavier trains, which in turn makes train handling more difficult, gradients of a high standard must be provided. The standards that have been set for the link lines are:

   (a) (i) Ruling grade for all lines except (ii) 1 in 100 comp
       (ii) Sentraran-Ofi-fantsfontein/Kaalfontein: this line takes off from the 1 in 66
            Germiston-Pretoria line 1 in 66 comp

   (b) Minimum holding grade at stopping signals on
       lines over which the following type of trains will
       operate:
       (i) Long heavy trains 1 in 200
       (ii) General goods trains 1 in 150
       (iii) General goods trains on (a) (ii) 1 in 94

   (c) Minimum length of grade (as far as practicable) 1 km

4. Horizontal curvatures:

   (a) Minimum radius — general 800 m
   (b) Minimum radius of curves at junction points
       with existing lines and new lines 600 m
   (c) At junction points in heavy built-up areas where junctions are difficult and
       tight each case dealt with on merit

5. Vertical curves. The present minimum standard
   rate of change 0.040 m/20 m/20 m is retained.

6. Major structures for water courses, roads, etc have been planned to accommodate the ultimate number of tracks; some are designed to cater for initial requirements only but making allowance for extensions as required.

7. The link lines shown on Fig 1 will be provided as follows:

   X — double lines in 1982 and 1983
   Y — single line with partial doubling in 1984
   Z — (anticipated) double line in 1985/86

   Not marked — Future

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**Brief description of sequence of movements through a module**

**In the arrival yard**

When a train approaches the complex on one or other of the link lines it will arrive on the peripheral or ring road (track) along which it will travel until it reaches the turn off to the module for which it is destined.

After the train has been brought into the arrival yard under signals the main line locomotive(s) will be detached and proceed direct to the locomotive staging tracks near the arrival yard for inspection and/or servicing. Locomotives that are used for hauling traffic between yards in the Reef/Pretoria complex and Sentraran will proceed directly to a departure yard after being detached from their loads.

In the meanwhile the wagon numbers will be checked against those appearing on a list and the list corrected where necessary while the wagons themselves will be examined by the carriage and wagon staff who will indicate which wagons require attention.

**In the main sorting yard:**

Two sets of shunting locomotives will operate at the hump; while the first one is pushing a load over the hump the second one will proceed to the incoming end of the arrival yard, attach itself to the rear of the next load to be humped and push it forward until it is just clear of the load being humped. It will wait here until the first set of locomotives has completed its task and then move forward on to the hump. By this time the staff on the hump, whose duty it is to uncouple the wagons, will have been supplied with a cut list.

Uncoupling is done as the load is pushed forward at a speed of 1.0 m/s. The cuts will accelerate down the hump creating sufficient gap between any two cuts to permit the relevant turnout being switched between them. Switching of the turnouts is performed automatically under computer control in accordance with the requirements of the cut list.

Certain wagons will by-pass the hump for various reasons and be placed on special tracks whereafter they will be handled by locomotives at the far end of the module.

**At the far end of the module**

Four sets of shunting locomotives will operate at the far end of the module. One set of locomotives is responsible for clearing the traffic from sorting tracks 1 to 32 to either a holding road when secondary sorting is necessary, or direct to a departure yard. A similar arrangement applies to the second set of locomotives which clears sorting tracks 33 to 64.

The other two sets of locomotives are responsible for clearing traffic placed on their respective holding tracks, performing the humping operation at their secondary sorting yards and thereafter placing the traffic in their departure yards.

Depending on which defined zone the far end locomotives are operating in, they also handle traffic which has been placed on the by-pass tracks and all movements involved in handling livestock traffic.

**In the departure yard**

After a load has been marshalled and placed in a departure track a guards van is attached to the rear-end of it by one of the far end locomotives. A main line locomotive(s) is attached to the load at the front-end in readiness for departure. Before departure of the train examinations of wagons and brakes are carried out and vehicle lists prepared or checked.