Mini project report

on

Haul Road Maintenance and management in surface mines

by

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1. INTRODUCTION

- The management of mine haul roads has not been widely reported in the literature, primarily due to the subjective and localised nature of operator experience and required road functionality levels.

- How quickly the road deteriorates again (i.e. rolling resistance increases) will dictate when the next maintenance activity occurs.

All too often though, road maintenance is done with little recognition of the following:
i. **where** the maintenance was done (what road segment of the network); and
ii. **what** was done (blading, dragging, shallow rip and re-grade or re-sheet, etc.).

Once the root cause is recognised (structural failure), one can plan to fix the problem correctly (box out to remove softs and backfill and compact with selected base-layer material, re-establish the wearing course and compact).

It is important to remember that a RCA for mine road ‘failures’ is just as valid as it would be for any other asset. Excessive maintenance on poorly performing segments of the road network is symptomatic of some underlying design issue.

2. Road maintenance activities

- There are several key activities that encompass road maintenance, from routine or ‘patrol’ road maintenance (blading or grading), through to resurfacing, rehabilitation and betterment.

Figure 1 Road defect of sinkage, squeezing or potholing.

Figure 2 Road defect of sinkage, squeezing or potholing.

- The selection of a maintenance management program for mine haul roads should be based on the optimisation of these costs, such that total vehicle operating and road maintenance costs are minimised.

There is plenty of loose, unbound material on the road. It will require frequent blading, due to instability. But also consider the geometry here – note how the junction is on grade. Many of the problems here areassociated with accelerating ladentrucks from stand-still on grade and the high wheel torque, which shears the wearing course. Root cause is both the current wearing course itself (Sp too low), but primarily the poor junction geometric design

Geometry is most likely the issue here – the crown of the road isnon-existent. Water drains to the centre of the road. But also consider structure – maybe a soft spot under the road has resulted in this deformation. If that were the case (and DCP probing could confirm this), it would be necessary to remove the softs, backfill and compact selected waste rock and re-establish wearing course.

When a road looks like this after blading, one has a build-up of fines (clay, mud) on the surface and the grader is simply spreading this around, or if this material persists to depth (100–200 mm) then the wearing course is nowhere near specification. Root cause is lack of coarse fractions (up to 40 mm) in the wearing course – if it is a spillage issue, deep ripping, remixing and water (to OMC) and recompact the wearing course will bring the material back to specification (if the spillage build-up is deep, blade it off the road and remove first) to expose ‘original’ wearing course.

Two issues apparent here, first, tyre tracks in the road indicate a wearing course material either poorly compacted or, in its compacted state, failing to reach the minimum 80% CBR required. Second extensive rutting is also seen (depressions in the road in the wheel paths of the truck), indicating too soft a structure to support the wearing course. The root cause here would be primarily structural – even the ‘best’ wearing course will not perform well if the underlying support is poor.

The edge of the road is in poor condition as the road structure was not constructed as wide as the surfacing. It could quite simply be solved by moving the road boundary markers back onto the edge of the constructed road – if the operating truck width would allow for this. The root cause here is that the road was built for smaller trucks and now that larger trucks are in use, the road boundary markers have been moved out to accommodate 3.5x the width of the largest truck. But the construction width of layerworks (geometric design) does not extend this far so edge failure will occur.

There is oversize which may be either ‘base’ layer dump rock material showing through a too-thin wearing course layer – or a poorly sized wearing course itself. Blinding the top of the base layer may assist to prevent these protrusions. If that is not the issue then the wearing course may be too thin (due to erosion, routine maintenance or normal gravel loss) and a resurfacing is due

3. Routine haul road maintenance

3.1 Routine haul road maintenance – untreated wearing courses

Irrespective of the maintenance management system used, there are some key elements of ‘good practice’ of mine road routine maintenance that should be observed for either type of unoptimised management approach:

- Typically managed by daily inspection of the road network and a subjective assessment of road segment functionality and maintenance priorities.

- Scheduled maintenance – road network is maintained according to a fixed schedule or frequency, irrespective of the actual functionality of the road segment being worked.

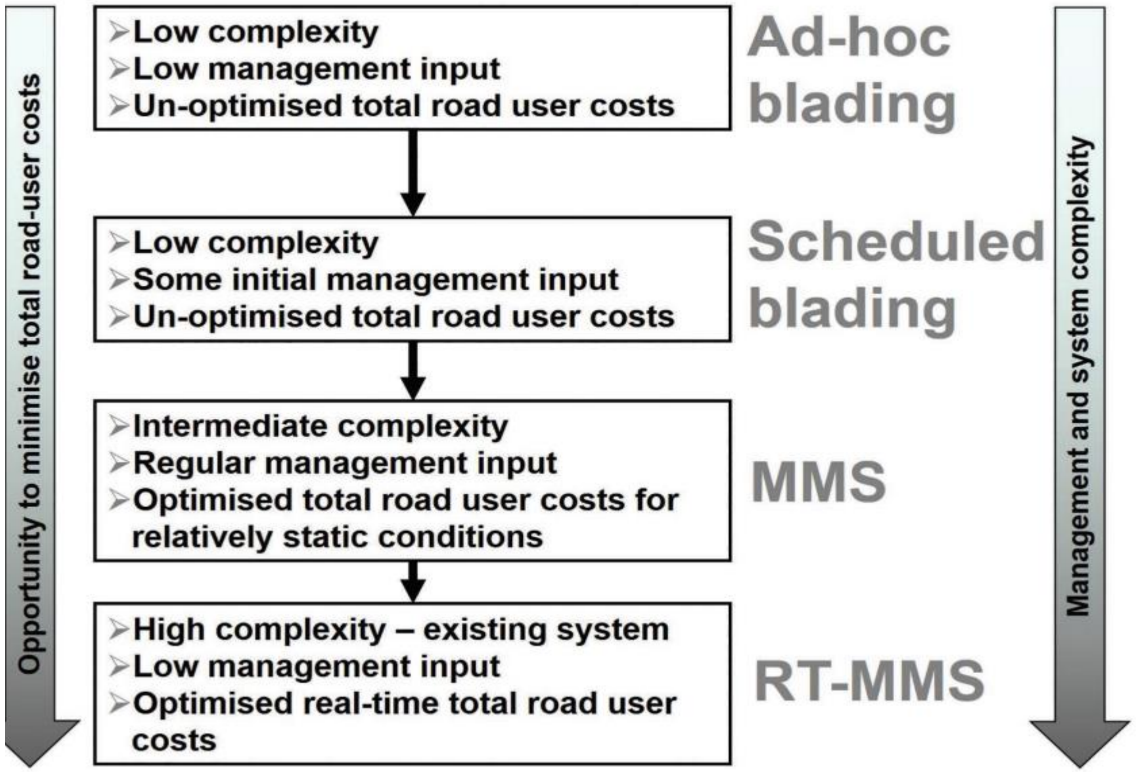
- Good grading practice consists of lightly watering the haul road to be maintained (or maintaining after rain) and then conducting the following:
    - Winning and recovery of wearing course passes
    - Removing defects, shaping and mixing passes
    - Spreading passes

- Scarify or top up the wearing course surface material to bring coarse fresh material to the surface – especially when the surface slicks up since surface spillage (mud, etc.) will change the characteristics of the wearing course if left on the road. This is often seen as laminations (layering) of fine material

Table 1 : Types of road maintenance activities.

Mode	Activity	Effect
Routine (Patrol) Maintenance	Spot regravelling	Fill potholes and depressions and exclude water
	Drainage and verge maintenance	Reduce erosion and material loss, improve roadside drainage
	Dragging/Retrieval	Redistribute surface gravel
	Shallow blading	Fill minor depressions and ruts and reduce rolling resistance
	Dust control/watering	Reduces loss of binder and generation of dust
Resurfacing	Full regravelling	Restore thickness of wearing course.
	Deep blading	Reprofile road and reduce roughness. Remix wearing course material provided that the wearing course has at least 100 mm of gravel.
Rehabilitation	Rip, regravel, recompact	Improve, strengthen or salvage deficient pavement.
Betterment	Rehabilitation and geometric improvement	Improve geometric alignment and structural strength.

Fig 3 Hierarchy of haul road management systems.



.• Remove spillage and other loose material from the road surface – do not leave as windrows.

• Repair areas that have slumped or settled or wet spots by backfilling with base or wearing course as appropriate.

• Maintain drainage on road and shoulders as per specification (keep roadside drains open).

• Maintain or re-establish cross fall/crown and super-elevation profiles.

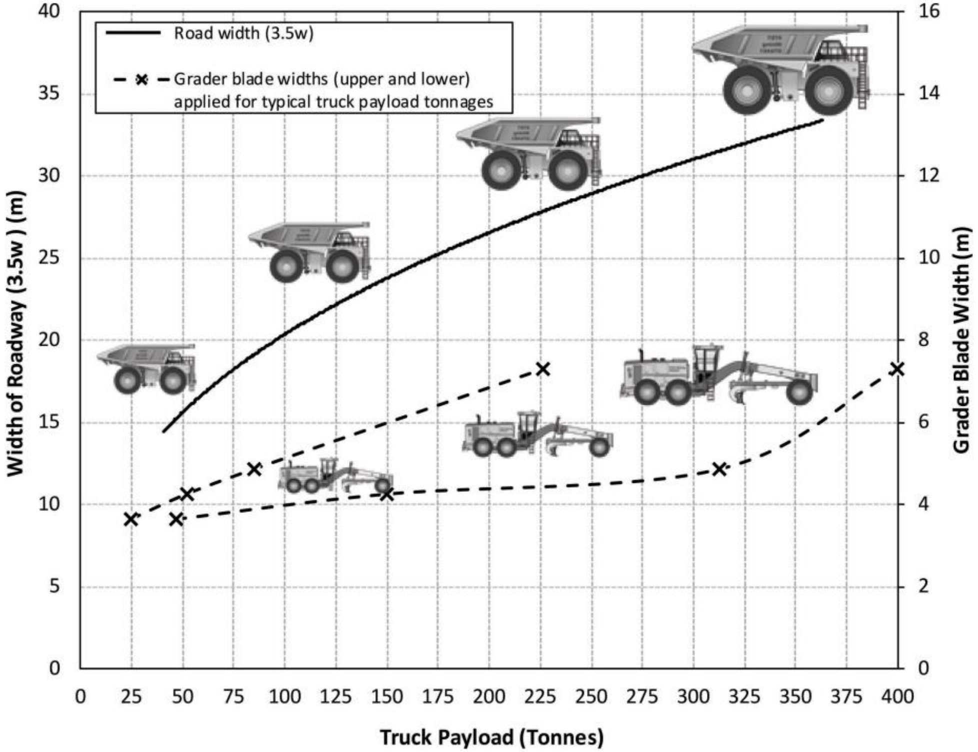


Fig 4 .Matching the size of grader with the truck size and road width.

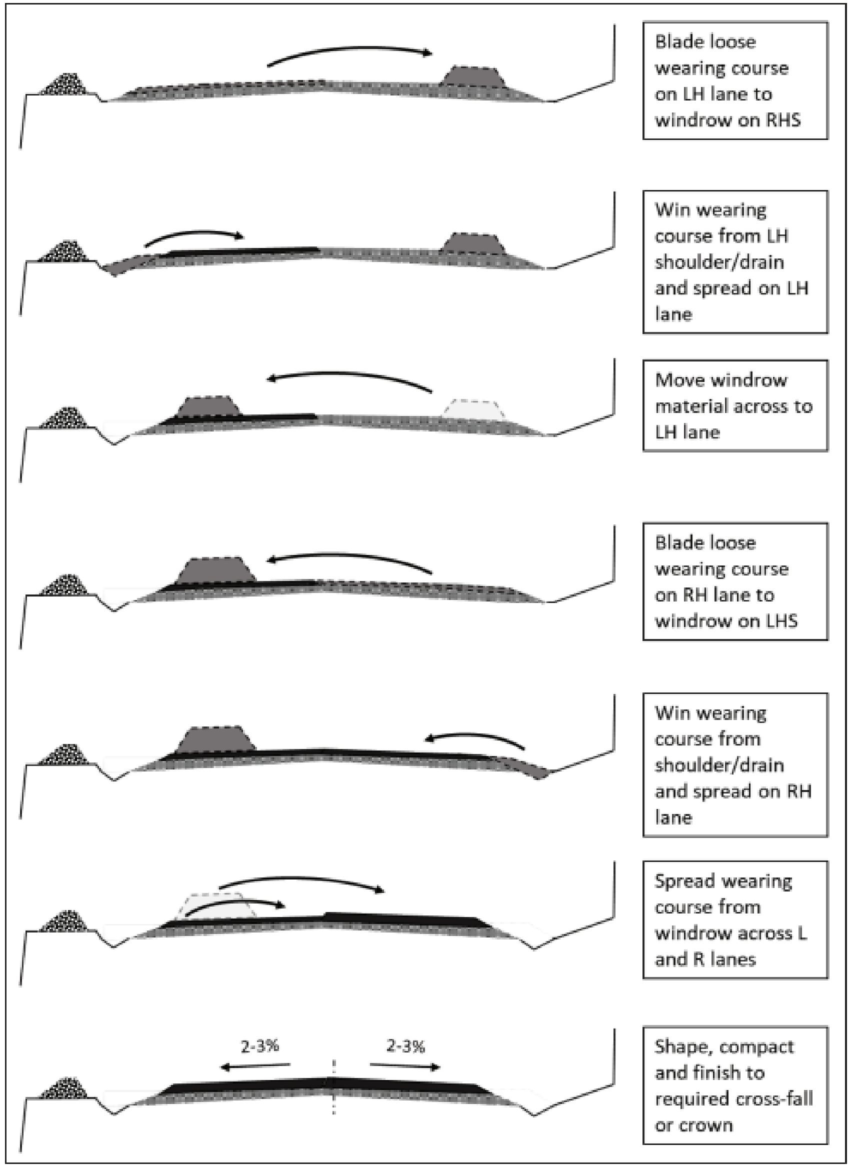
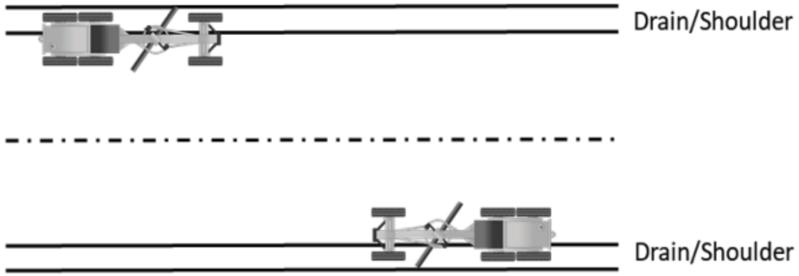


Fig 5. Grader passes required to win wearing course from shoulder and drains to reestablish profile of road.

- When finishing the haul road, the moldboard top-edge should lead the toe (cutting) by 150 to 250 mm to maintain a cutting edge approximately normal to the cut surface. Resurfacing the road will eventually be required to restore the thickness or specification of the wearing course and should be done:

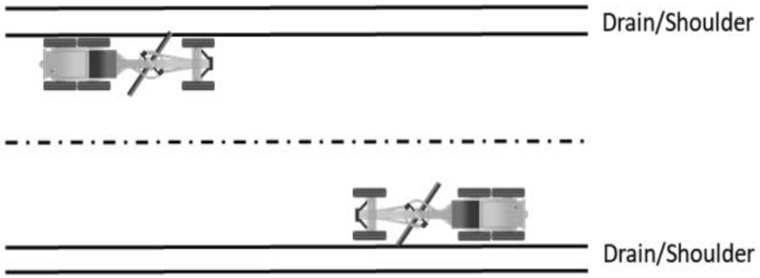
i. at the first indication of significant distress under traffic (a larger number of defects
which require intensive maintenance activities);

Winning and recovering material passes (drains and shoulders)



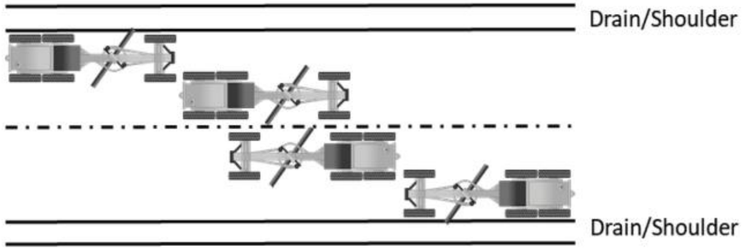
Blades angled as close as possible to 45° to recover/win wearing course from drain and shoulder. First and second pass apply where a crowned profile is maintained. For a cross-fall across width of road, win only from the drain side. In all cases avoid blading spillage on to the road.

Cutting road surface, removing corrugations and defects and mixing



Blade hard on surface and scarify if blade not cutting to bottom of corrugations or other defects. Multiple passes in each direction may be required to reach the centre of the road from both sides.

Spreading and finishing



Two or more spreading passes will be required depending on the amount of material obtained. If a crowned profile is to be maintained, the blade must not extend beyond the centre of the road. When a cross-fall profile is adopted, blading can be applied in successive passes across the full width of the road, working up from the drain side

ii. before the base layer begins to protrude through the wearing course (i.e. at less than 100 mm thickness);

iii. if the wearing course material has weathered and eroded such that it no longer meets functionality requirements;

3.2 Routine haul road maintenance – treated (palliated) wearing courses

- The routine maintenance requirements of a palliated or stabilised wearingcourse are significantly different from a conventional wearing course and greater emphasis is placed on road ‘cleaning’ as opposed to road defect removal and gravel redistribution. Spillage and especially fines imported onto the road surface from truck tyres needs to be removed and often, the road surface itself would be treated again, with a spray-on maintenance (re-) application to bind any remaining loose particles on the surface.

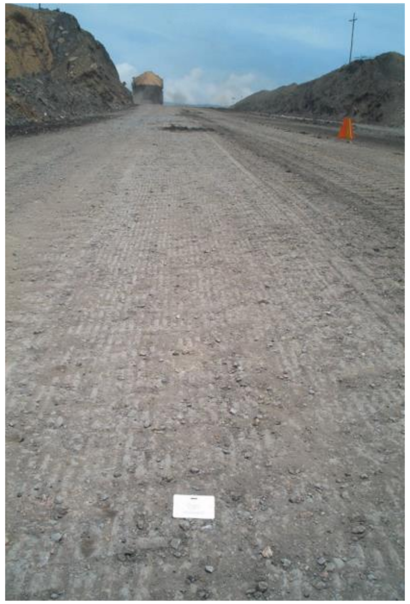


Fig : 6 Example of toothed grader blade (L) and resultant road surface finish (R).

- Toothed or scarified blades attached to the grader moldboard work best with the tilt of the moldboard set back to 70°. If the tilt angle is not correct, chattering or vibration will occur.

- This treatment is useful to remove minor functional defects whilst at the same time not totally destroying the hard-running surface.

- A motor-grader would not be efficient in removing dust, and cutting the hard surface has to be avoided. The maintenance strategy has to be adapted, and often a rotary broom shown in Figure 7 is used.

- An alternative procedure would be to use a truck-mounted vacuum cleaner, as is used on some diamond mines, to collect the dust without abrasion.

Figure 7 Rotary broom and dust cloud generated by brooming.

- However, in doing this it is important to note that the fundamental characteristics of the wearing course will change as a greater proportion of fines become embedded on the surface of the road and as a result, functionality, especially wet- and dry-skid resistance, will deteriorate, along with the creation of thin laminations made up of layers of fine treated material.

4. Maintenance management systems (MMS)

- Systematic approach to road maintenance, referred to as a maintenance management system (MMS).

- This approach considers how quickly roads deteriorate under the action of traffic and how deterioration impacts vehicle operating costs, compared with how much it would cost to maintain the road (both costs being carried by the mine or transport contractor) measured against the benefits of an improved road performance.

- The concept is shown in Figure 8, where total costs comprise vehicle operating costs (VOC) and road maintenance equipment and application costs.

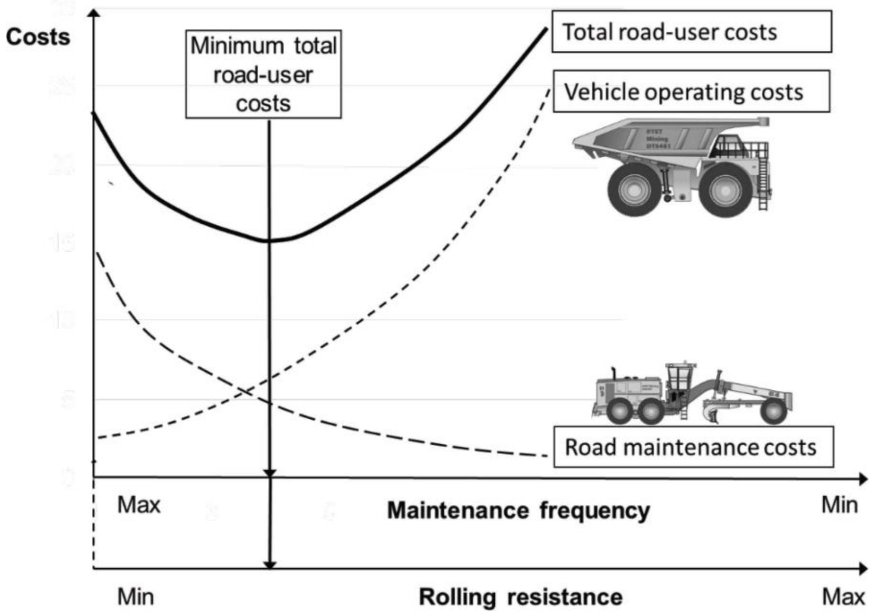


Fig 8 :Concept of MMS – determining the optimal frequency of road maintenance commensurate with minimum total road-user costs.

- To apply very frequent maintenance to the road, it would be advantageous to truck costs through a lower overall rolling resistance, which would reduce fuel burn, cycle times, etc.

- This optimisation approach is inherent in the structure of the MMS for mine haul roads. Two elements form the basis of the economic evaluation, namely these:

  i. haul road functional performance – rolling resistance-based model of deterioration; and
  ii. vehicle operating (VOC) and road maintenance cost models

- MMS is designed for a network of mine haul roads, as opposed to a single road analysis. For a number of road segments of differing wearing course material, traffic volumes and speed and geometric (grade and width) characteristics, together with user-specified road maintenance and vehicle operating costs, the MMS approach can be used to determine the following:

  i. the maintenance quantities as required by the particular maintenance strategy;
  ii. the vehicle operating and road maintenance costs; and
  iii. the optimal maintenance frequency for segments of the network such that total road-user costs are minimized.

5 Minimising total costs across a network of roads

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- Central to the cost of truck hauling is the concept of resistance (expressed here as a percentage of Gross Vehicle Mass [GVM]). Rolling resistance is expressed in terms of kg (or N) resistance per ton of GVM, where approximately 10 kg/t = 1% rolling resistance or 1% grade (against the direction of travel).

- Whilst rolling resistance is to some extent a controllable variable in a mining operation, grade resistance is more typically fixed and is a function of mine geometry and ore: waste stripping ratios, etc. As discussed each truck has an optimal grade at which travel time is minimised between the limits of
  i. a long-haul distance, but high-speed, low-gradient haul route;
  ii. a shorter-haul distance, but low-speed, higher-gradient haul route;

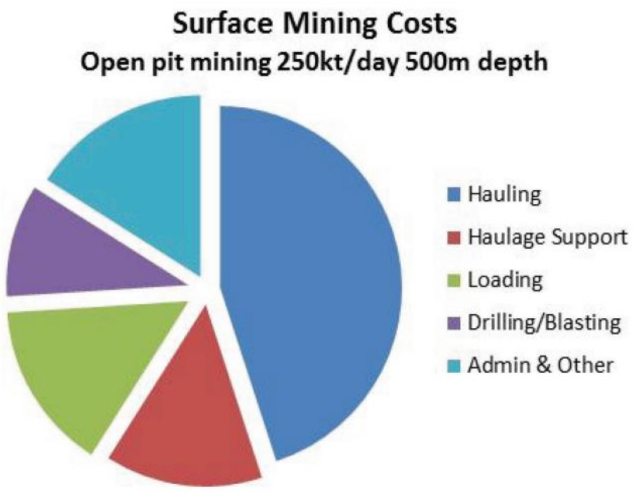

Fig 9: Typical cost breakdown for a deep open-pit operation.

- Tyre penetration that typically specify a 0.6% increase in rolling resistance per centimetre tyre penetration into the road, over and above the 1.5% (radial and dual wheel assemblies) to 2% (cross-ply or single wheel assemblies) minimum resistance. Thus a 2 cm tyre penetration would equate to a rolling resistance of 2.7% for a rear dual assembly. In using this approach however, note should be taken of the following:
  - Tyre ‘penetration’ in this context can also equate to road surface flexure, displacement under the tyre will be minimised and rolling resistance approach the minimum for the road condition.
  - Tyre inflation pressures and tyre tread patterns can also influence rolling resistance.

approach adopted in the following sections when an estimate of rolling resistance is required :

1. Haul truck speed and cycle time estimations :
   - Speed rimpull gradeability curves
   - Coopers speed estimation models
   - Spline estimation techniques
2. Vehicle operating cost models
3. Road maintenance cost models
4. Tyre cost models
5. Tyre cost models In the analysis of tyre costs.
6. Optimising management of mine roads

6. Optimising management of mine roads

- Mine haul road maintenance frequency is closely associated with traffic volumes, operators electing to forgo maintenance on some sections of a road network in favour of others.

- Two elements form the basis of the economic evaluation, namely these:
  i. haul road functional performance – rolling resistance model or deterioration; and
  ii. vehicle operating and road maintenance cost models.

- The MMS flow chart used to determine the optimum maintenance interval for a mine road network consisting a number of variable road segments. Cost savings associated with the adoption of a maintenance management system approach are dependent on the particular hauling operation, vehicle types, road geometry and tonnages hauled, etc.

- The first element of a MMS for mine haul roads is based on modelling the variation of vehicle operating costs with rolling resistance. When combined with a road maintenance cost model, the optimal maintenance strategy for a specific mine haul road, commensurate with lowest overall vehicle and road maintenance costs may be identified

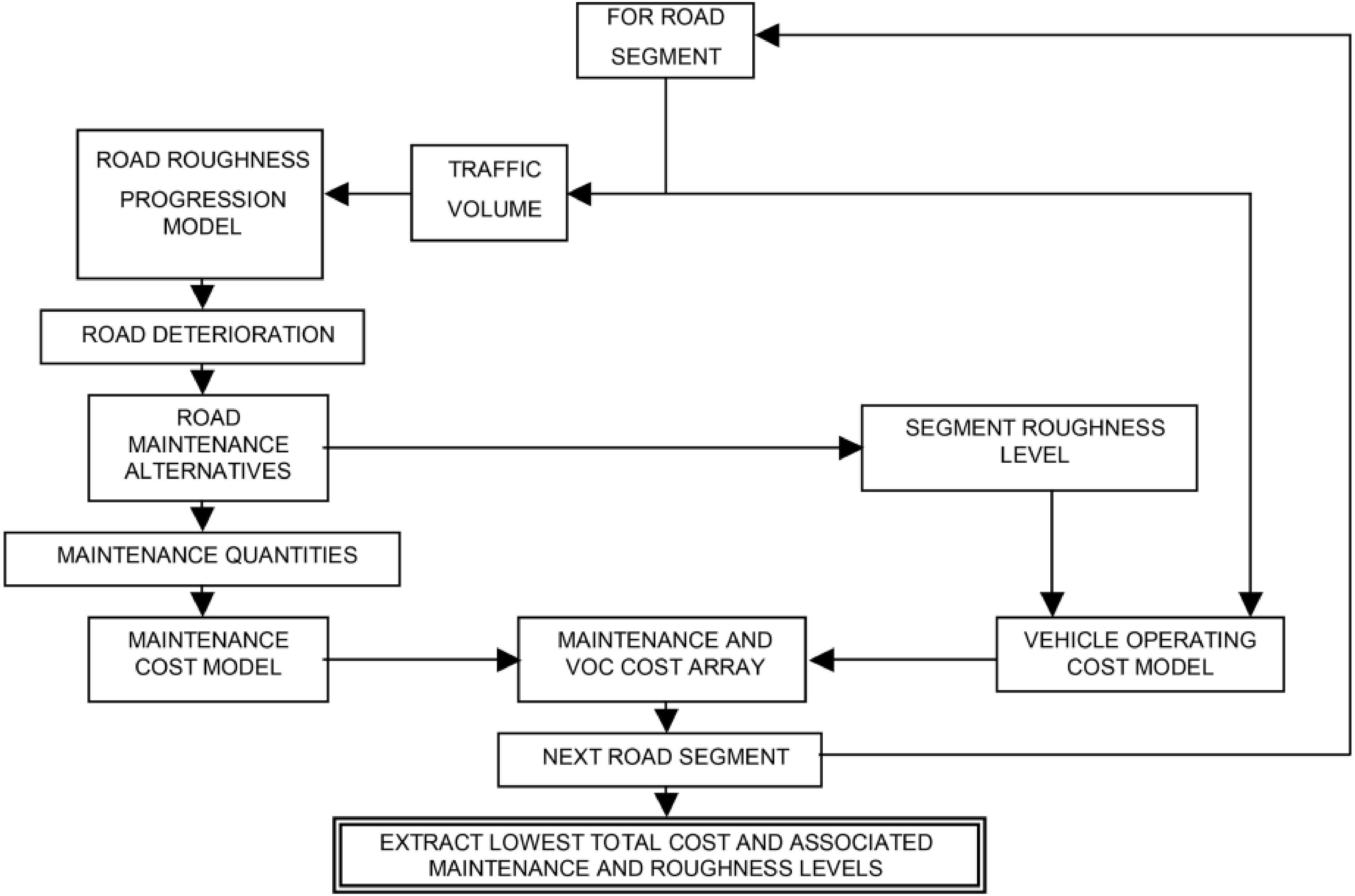

Figure 10: Flow diagram of MMS for mine haul road network (for a single maintenance strategy iteration).

7. Real-time road maintenance

- The most cost-effective approach to mine road network maintenance management is based on a real-time system which integrates truck- and pavement-interaction data as a basis for making road management-based decisions. Most large surface mines already utilise a high precision GPS and data communications system backbone for asset management purposes.

- mathematical modelling developed a more rigorous analytical methodology to integrate multi-sensor information to eventually isolate, recognise and dimension a road defect from its vibration signature and other on-board diagnostic data sources.

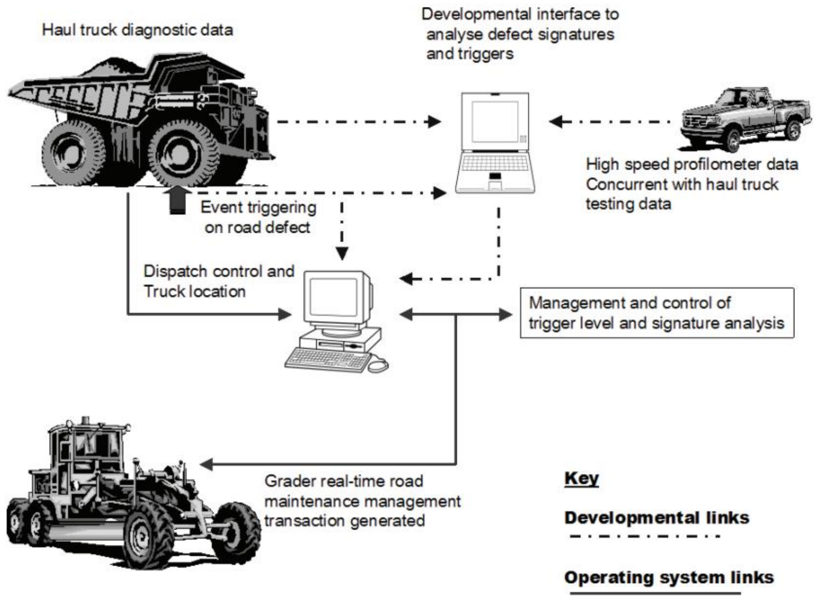

Fig 11 :Real-time mine road maintenance system concept and integration with existing mine-wide communication, location and truck monitoring systems.

- Development of RT-MMS approach further to include a lowcost ‘bolt-on’ road condition monitoring (RCM) system to record and transmit a road condition score for site benchmarking and road maintenance management purposes.

- Although it simplifies to some extent the haul truck characterisation exercise of Hugo’s approach, it nevertheless suffers from some of the same issues with respect to separating driver-and truck-induced responses from true road responses.

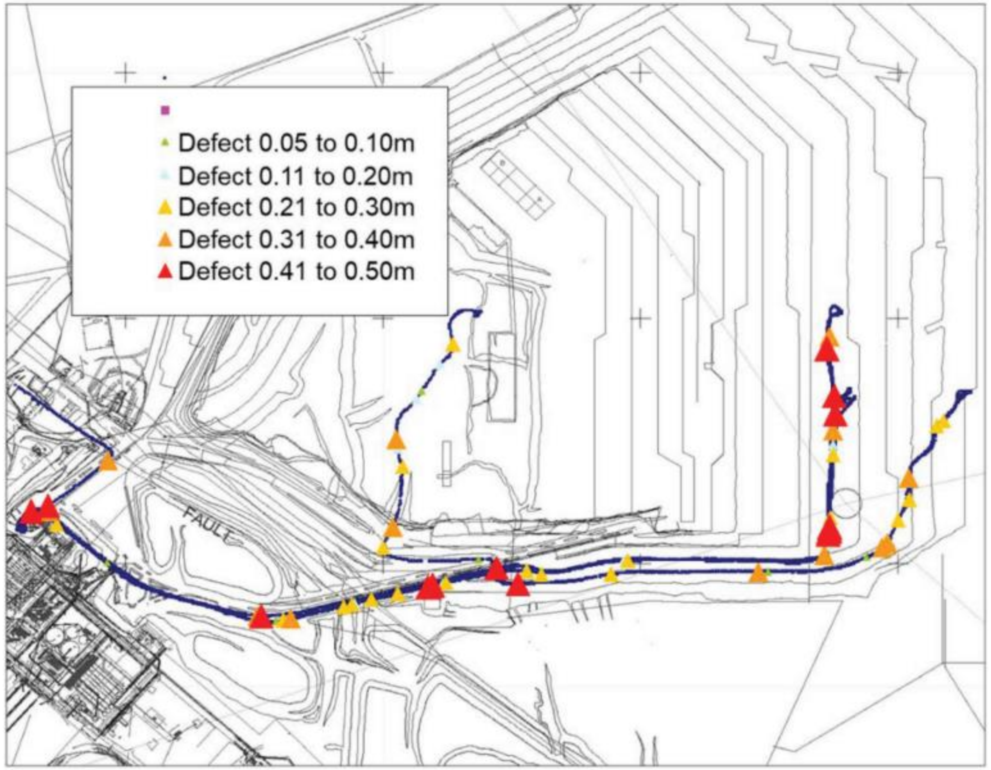

Fig :11Real time road defect geometry measurements. Symbols represent defect magnitude (depth or height).

- The road condition monitoring system provides full site mapping, showing the state of the road in a simple colour graded format indicating the different levels of road condition or defect severity, allowing required maintenance locations to be identified and road maintenance triggered.

- Other approaches to RT-MMS field evaluation of rolling resistance using each tyre of a mine truck as a measurement device, capturing the tyre load response and coupling this with a cyclic plate load test of various locations on a haul road to establish the resilient pressure stiffness and its variation along a road.

- The latter supplies the ground deformation, which when evaluated in parallel with the tyre deformation establishes the tyre-ground contact area and thus permits the rolling resistance to be evaluated.

Fig :12 Example of road condition monitor (RCM) output.

- The key to all the RT-MMS systems is both the measure of road condition and how that condition is evaluated in terms of its impact on total road user costs.

- Whilst rolling resistance is the most widely understood parameter from a mine operator’s perspective, it is especially problematic to measure on a real-time basis and indirect measurements may prove to be the most tractable approach in the future.

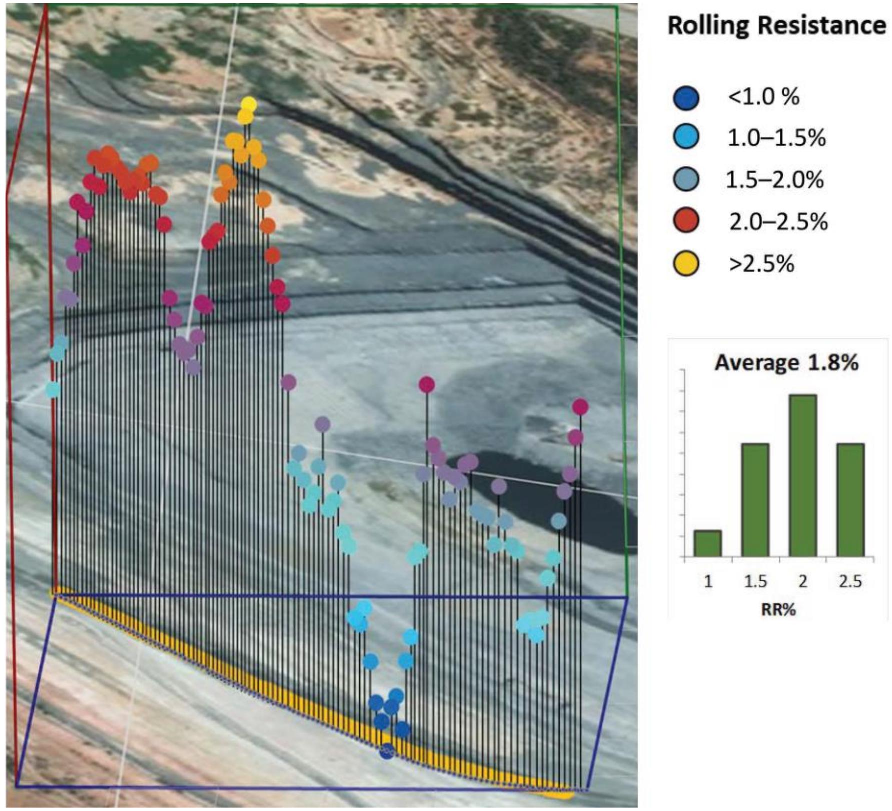

Fig 13 :Estimation of rolling resistance for RT-MMS using speed-rimpull gradeability and on-board data, plotted along selected portion of laden truck haul.

- Once road condition information (either as defects, IRI or rolling resistance, etc.) is received by the communications hub on the mine and the appropriate weighting applied (for traffic volumes, condition severity, etc.).

- A transaction can then be initiated to automatically inform road maintenance assets of the location, type and, critically, priority. Road rolling resistance can also be deduced on a similar basis, thus areas of high rolling resistance (which may not be associated with a particular road defect, but rather a high density of defects on a given section of road) can also be recognised and repaired on a real-time basis. By combining on-board data and defect recognition within the broader mine-wide asset management and communication system.

Other associated benefits derived from this approach are as follows:

- Event map histories which show consistently poor sections of road requiring betterment or rehabilitation.
- More effective utilisation of existing road maintenance assets: rapid response to identified road defects.
- Reduced capital expenditure on road maintenance assets: expanding road network can be effectively maintained with less equipment.
- Immediate recognition of haul road conditions – visual inspection for each change of hauler route unnecessary.
- The increased utilisation of the existing computer-based mine and transport management system to provide stream-lined and integrated data management and information.

8. CONCLUSION

- Haul road maintenance emphasizes the importance of proactive and data-driven strategies to optimize road conditions, enhance production efficiency, reduce maintenance costs, and improve operator safety and morale.

- By leveraging real-time strut pressure data, payload readings, and GPS coordinates, mining operations can identify and prioritize sections of haul roads that require maintenance, leading to quantifiable improvements in production, maintenance costs, and operator well-being.

- The significance of adopting advanced monitoring technologies, prioritizing road maintenance based on data-driven insights, and continuously improving maintenance practices to achieve optimal haul road conditions, operational efficiency, and overall cost-effectiveness in mining operations.

- True predictive maintenance, focusing on road conditions influenced by truck speed, payload, and other factors, can prevent failures and enhance production efficiency.

- Utilizing real-time data on road conditions, such as strut pressure and payload readings, allows for intelligent road maintenance prioritization and dispatching of road crews to high-impact area.

- Improvements in production efficiency, reduced maintenance costs, and enhanced operator health and safety are the direct outcomes of effective haul road maintenance strategies.

- Road construction and vehicle depreciation costs were not considered since these will be similar irrespective of the maintenance strategy evaluated.

- The objective of maintainace for a mine haul road network is to evaluate alternative maintenance strategies within a system of constraints related to total cost and maintenance quantities such that the optimal maintenance policy for the network and maintainace also follows:

- The truck speed and fuel burn,
- The increase in rolling resistance
- It should also be noted that each segment also has a cost penalty associated with too frequent road maintenance, where the cost of road maintenance is not recouped through reduced VOC.

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