(A)

FIGURE 2

- Downtime
- Lost Time
- Available Time
Typical Detailed Interrogation Chart for Loaders and Trucks

For every machine an interrogation chart can be developed daily/weekly/monthly. Ideally the green portion should be two thirds of the pie.
**Planned Scheduled Services**
Maintenance of all equipment must adhere strictly to a maintenance policy whereby all work is carried out in accordance with planned schedules and, in this respect, it has to be stressed that strong discipline must be exercised over operators and mining supervisors to ensure that machines are made available in the workshop in terms of the schedule. For a MARC agreement it is of critical importance that the senior manager is committed to the engineering function and the OEM is backed by the TM3 engineer.

**Management Information**
If the management information system is working effectively the total history of any machine will be captured. However, it needs to be confirmed that all relevant information is recorded for work done, or not done, during servicing in order that any unfinished work can be completed before the next service is due.

**Missed Services**
There is a need to know if missed services occur for whatever reason. Deviation from the schedules can only jeopardise a planned maintenance programme.

**Operators’ Shift Report**
Cognizance of the operators’ shift report is important.

**Tools**
All artisans have to have their own tools and they must also have access to special tools; nevertheless there is a need to audit the status of artisans’ tools regularly. The security of tools can be a major issue and it is critical to control it.

**Drifters**
Drifter maintenance cycles have to be adhered to and it is important that there is an adequate number of drifters in the system.

**Oil Sampling**
Regular oil sampling can prevent damage to moving parts in engines, transmissions, differentials and hydraulic systems. Early damage from dirt and heat build-up can be detected before serious damage occurs. A standard procedure is necessary.
ENGINE DOWNLOADS
Transmission/Idle Hours

FIGURE 6
Artisans Bonus
It can be an advantage to have an artisans bonus scheme.

Standard Procedures
Standard procedures and practices are necessary for work carried out in the workshops and these should be audited internally.

Procedure Manual
All procedures and practices should be incorporated in a policy maintenance manual.

2.5 Engine Downloads
Important information can be obtained from engine downloads. For instance, a split of engine hours recorded for LHD’s/trucks can identify idle hours and transmission hours (or work hours). Refer to an interrogation chart in Figure 6. In this chart the lost time can be seen as 25% but in reality it is 45% (white segment plus the yellow segment showing the idle hours).

2.6 Workshops
The establishment of well-planned workshops for the start of a new mechanised project is essential for success. For projects where equipment is considered captive underground, as was the case at Cooke 2 REGM where projects were started up three kilometres inbye of vertical shafts with no access by underground decline, the infrastructure must provide the service for the first life of the total fleet. It is important to set out a detailed barchart for any new workshop with cognizance being taken of the following ‘milestones’.

Layout
Final layout plans with a rock support plan submitted by the geotechnical engineers.

Schedule of work
Detailed schedule of development work (excavations), including all the necessary support work.

Contractor Involvement
If the work is to be carried out by a contractor, tender enquiries must be issued; tenderers’ bids submitted and scrutinised; the final decision made on bids; site establishment by the appointed contractor; date for completion of construction work.
**Equipping and Commissioning**

Establish a detailed schedule for equipping and a date for commissioning.

There are many requirements for an efficient underground workshop to serve the full fleet of equipment at steady state: washbay to collect water and provide oil separation; sufficient workbays for final fleet size (based on 85% availability assuming 15% of total fleet equipment being serviced plus additional bays for UV’s, personnel vehicles and provision for damaged vehicles captive for a period of time); adequate lifting arrangements (say 10 ton cranes); boilermaker bay; electrical bay; hydraulic store; a store of adequate size for parts and spares; secure place for special tools and tools for artisans; communication system from the workshop to surface (telephones, optic fibre, leaky feeder, WLAN as decided); office facilities, computers, archives; oil and grease dispensing arrangements; a diesel re-fuelling facility and storage tanks and a fuel pipeline to the workshop storage tanks from the surface tanks; tyre bay and a store for assembled wheels. A most important requirement in the case of operations from a vertical shaft, as against where a decline from surface has been developed, is the establishment from the outset of an assembly bay at the entrance to the workshop, at the end of a rail haulage or at the shaft bottom. The assembly bay is where the machines stripped on surface, before being slung down a vertical shaft, before being re-assembled. This bay will also serve as a dis-assembly area when machines are stripped to go to surface at the end of their first life. Finally an issue not to be overlooked is the necessity to guarantee easy access in and out of the workshop for all equipment. The movement of machines has to be streamlined: congestion at the entrance to the workshop will strangle the operation and cause aborted services to occur, not to mention the total frustration of an inefficient engineering function.

Over recent years the experience of KAR has shown that underground workshops are often poorly designed and sometimes require re-design, re-equipping or even the need to establish new workshops; in these cases an interim short term strategy may be required which could mean the construction of satellite workshops closer to the workings or the carrying out of services on two shifts but not night shift if the maintenance standards are not to deteriorate.
2.7 Stores
The actual stores physical capacity must be adequate; this applies to the underground store in the workshop and the holding store on surface.

2.8 Stores System/Strategy/Spares Availability
A reliable stores system has to be in place if there needs to be a timeous supply of spares and sub-assemblies to the underground workshop and in the workshop, stores must be physically secure. The system must be able to provide for adequate stock levels to take account of any constraints in the mine infrastructure.; this may be in relation to vertical shafts, shaft stations, locomotive haulages, all of which can cause bottlenecks in the system. In the case of mines situated in remote areas, due to logistical issues it is even more important to maintain sufficient spares at the mine.

In addition, it is important that there is an understanding of the availability of the different categories of spares and some comments here are relevant.

Preventive Maintenance
These spares are used on a weekly basis for the servicing of machines and can be clearly defined and therefore they should represent a low risk of not being available.

Critical Spares
These spares are many but are essential when breakdowns occur. Their requirements can be unpredictable and the risk of not being available can therefore increase. The lists and stock levels of these spares require a close scrutiny in order to minimise risk.

Major Components
These large sub-assemblies and components are usually only required at long intervals in the life of the machine: refer again to Figure 1 for spikes. For these reasons and also for their high cost the risk of their availability when they are required, or more importantly when early failure occurs, is always high. There is always going to be a certain risk for these spares or sub-assemblies but mine management need to know what these risks are.

2.9 Operator Skills/Training
It has long been known, indeed for decades, that it is axiomatic to have skilled drivers for maximum performance and also to prevent abuse and
damage to equipment. The selection of operators is critical. It is important to provide a profile analysis of new candidates by means of phsycometric testing in addition to the testing of mechanical skills. The OEM provides initial training programmes for operators as part of their sales package. Control over these programmes by the OEM is designed to ensure that a trainee does not automatically pass and certain rules have to be followed.

2.10 **Artisan Skills/Training/Retention**
In any MARC agreement it is the responsibility of the OEM to maintain the equipment and therefore the onus is on the OEM to employ competent artisans at all times. For the OEM to do this specific guidelines must be followed. Firstly, they must set out a training policy and a practical training programme. Secondly, they must identify, by means of an audit, what skills they actually have at the start of a contract. Thirdly, they have to make arrangements for all artisans to attend a training course on the specific machines they have supplied to the mine; artisans must obtain accreditation for these courses. It is the OEM's responsibility to ensure that there is a full complement of qualified artisans employed on the MARC. Fourthly, the OEM must retain their artisans when trained. In this respect, a significant bonus should be paid to artisans if the availabilities reach the required target but only to be paid to those artisans responsible for that equipment. Finally, there has to be a focus on rig maintenance (face rigs and bolters) and consideration should be given to the appointment of a drill rig master mechanic with a specific job description on appointment; this appointment can be very important in any situation where only average skills exist.

2.11 **Damage/Abuse**
Damage and abuse of equipment is common throughout the mining industry world-wide, with subsequent high costs of damage repair and a loss of utilisation of equipment. In the opinion of KAR there are two factors which will reduce damage markedly. The first is the establishment of good operator skills; damage can be especially high when operators' skills are only average. Secondly, the appointment, at an early stage, of a mechanical equipment supervisor (MES) has been proven to assist in reducing damage and abuse of machines as the primary duty of an MES is to maintain driver discipline. The MES will also
be directly involved in damage investigation. The duties of an MES will be further discussed.

The cost of damage can be very high. At Waterval damage costs peaked at about R1,2 million/month, which represented 25% of total variable costs payable to the OEM. On a visit by KAR to Trout Lake, a mine in Canada owned by Anglo American (Hudson Bay Mining and Smelting Company), the damage costs were about 0,5 million CAD/year or approximately 7% of the engineering budget. These costs are always related to proven damage but the real cost of damage can be significantly higher and more importantly the loss of production caused by damage is difficult to quantify but can be significant.

2.12 **Mechanical Equipment Supervisor**

The importance of appointing a mechanical equipment supervisor (MES) cannot be overstated, specifically in developing a new trackless operation on mines where conventional labour intensive mining was common practice. At REGM, where KAR pioneered trackless mining, it was realised by KAR from the outset that the training of operators to an acceptable level of competence and the establishment of driver discipline were paramount for the success of the projects. In this respect, the early appointment of an MES was made at the operations at REGM and also at H.J.Joel Gold Mine.

The MES had a legal appointment in that he was delegated by the responsible engineer to test the competence of any driver before issuing him with a licence. In addition, in terms of an instruction from the senior manager, the MES had the authority to promote or demote any driver if he should deem it to be necessary. This authority wielded by the MES provided the basis for establishing and maintaining driver discipline. Therefore, it is with this experience in mind that it was believed, and still remains the belief, that the appointment of an MES on any new trackless project will enforce driver discipline. There are many other duties of an MES and a full list of these, set out by KAR in the 1980’s, are seen listed in Figure 7.

2.13 **Underground Access/Logistics**

Unless there is a direct access by a decline from surface to the underground workshop area there is likely to be major constraints to the logistics of the trackless operation. This can be further exacerbated if the
Duties of the Mechanical Equipment Supervisor

1. Select all new candidates for a job as an operator and ensure any new operator is trained according to best practice.

2. Review all operators' licences, interrogate all operators training background and re-appoint or re-train all operators: this to be done in terms of the proposed programme.

3. Train and appoint instructors to assist with establishing best practice.

4. Maintain a total on-going re-training programme for all current operators.

5. Assist and co-ordinate supervisory training. Initially set up appreciation training for supervisors and management for good and bad practices.

6. Exercise driver discipline over the entire complement of operators on a daily basis. Remove incompetent or ill-disciplined operators for re-training; this to be done by the MES with the full authority of the manager in charge of the shaft.

7. Investigate damage and abuse of equipment by operators and, further, liaise with the responsible engineer in terms of damage report investigation.

8. Enforce TM3 standards.

9. Follow-up on the use of the operators' check list.

10. Enforce correct drill string procedures (collaring, bit removal etc.).

11. Work in close co-operation with OEM's on their proposed training programmes and their audits of both machines and operator practices.

12. Submit a daily report to the senior manager in charge of the shaft.

FIGURE 7
workshops are at the inbye end of a locomotive haulage which is also used for rock handling and transport of material and persons. It therefore becomes vital to de-bottleneck and streamline the transport of engineering spares, fuels and oils for the trackless fleet. In these circumstances it would be advisable to introduce a fuel pipeline (possibly also for oils) from surface direct to the workshop re-fuelling area, as was done by KAR in the 1980's on all the early projects at REGM and H.J.Joel Gold Mine.

Where no decline exists and access is by vertical shaft, which already exists or is planned for from the outset, it would be an advantage to plan for a large cage in order to be able to split machines into a minimum number of components for transfer underground; this was planned for at H.J.Joel Mine. At existing vertical shaft systems the possibility of driving a decline from surface should not be disregarded without an investigative study.

2.14 **Communications**
There should be some communication link from surface to the underground workshop complex including the store, which may be telephones, computer and internet linkage by optic fibre or WLAN.

2.15 **Tools**
The OEM has the obligation to provide their artisans with all the necessary tools to meet the requirements of a MARC agreement. Some sort of procedure and audit must be in place in order to avoid constant shortages; this procedure should provide for issuing, use and security of personal tools. There must be a separate agreement for the use of special tools which have to be available at any time they are required.

2.16 **Re-Build/Scrap Policy**
Notwithstanding that a fleet of equipment is new at the start of the project, it is necessary from the outset to set out a policy for major re-builds of machines or whether they will be scrapped and re-placed. An analysis of historical data and trends from the computerised management information system will assist in deciding the right time as to when to remove machines from underground to surface for re-build or to scrap the machine. This policy must take account of the need to provide for ‘swing’ machines in order to maintain the full complement of machines in the fleet, to ensure the production call is met.
2.17 **Supervisory Training**

The importance of operator training has been stressed. It is also important that training courses for supervisors are also planned for. Although it is not a requirement for supervisors to be able to operate a machine to the level of competence of a licenced driver, they must know the basic functions of the machine and know how to operate it. In addition, they must also be aware of the possible abuse of the machine by the operator. If these skills are not acquired the supervisor cannot supervise effectively. The supervisory training would apply specifically to shift bosses and mine captains.

Further, it is equally important that managers and engineers are given an appreciation course for them to fully understand the best operator practice and in addition to acquire the technical knowledge to enable them to control and manage TM3 operations effectively.

2.18 **OEM Technical Support**

It is recommended that audits of the condition of equipment and driver skills take place on a regular basis by the OEM specialists. Also, every opportunity should be taken to gain updated technical knowledge from OEM engineers visiting the country.

2.19 **Cannibalization Policy Statement**

There is a definite risk that cannibalization of equipment can occur. This can easily happen when machines are stripped on surface before being transported down vertical shafts. There has to be an accountability when machines are dismantled and handed over to shaft personnel before being given back to the OEM in the underground workshops. However, cannibalization can take place anytime and it is necessary that a management directive is signed off by all responsible officials in order to curb this practice. A typical hand-written directive by KAR at H.J.Joel Gold Mine can be seen in Figure 8.

2.20 **Tyre Management**

Notwithstanding that a tyre contract agreement is likely to be signed by the mine with a tyre management company, there will be issues that the OEM will want that company to be aware of. Therefore it becomes the responsibility of the OEM to set out their requirements in a document and submit it to the tyre management company.
H. J. Joel Gold Mine

Management Directive

As of now it is strictly forbidden to cannibalize any mechanized unit.

Copies to:
Managers
Engineers
Mine Overseers
Engineering Foremen.

K. A. RHODES
MINE MANAGER
H. J. JOEL GOLD MINE

FIGURE 8
2.21 Trackless Mining Standards and Code of Practice

Trackless mining standards should be compiled and incorporated in a standards policy and procedure manual. In fact two such manuals should be prepared: mining and engineering. It should also be borne in mind that a code of practice has to be drawn up which is intended to improve health and safety matters related to the use of trackless mobile machines underground; this documentation is mandatory in South Africa.

In terms of a MARC agreement, there are certain standards which require the specific attention of both the mine company and the OEM but which are the responsibility of mine management.

Roadways

Poor roadway conditions, which can obviously cause a reduction in tyre life, will also affect the life of a machine (typically transmissions and axles on LHD’s and trucks), also its availability and the overall cost of maintaining the machine. In short, if any machine continues to work regularly on poor roadbed surfaces then major components will have a shortened life due to excessive wear. This of course would generally be the cost to the OEM but the lower availability of the machine will cause production losses to the mine and will inevitably result in disputes between mine management and the OEM. There are also certain elements which are relevant here and these are the design of the roadways including gradients and gradient changes; roadway construction by the use of imported crushed rock as a roadbed base; the maintenance of roadways with a grader; the control of water on roadways generally and specifically in declines, as water out of control will destroy roadbeds; pumping at the face whilst drilling; avoidance of rock accumulations on roadways; attention to the condition of sidewalls and the need to ensure that extra lifters are drilled in ramps and declines.

Cleaning

Where cleaning takes place cognizance has to be taken of the correct loading technique for LHD drivers to follow: all loose/fly rock has to be cleaned up before entering the muckpile; filling in of potholes; tramming distances for LHD’s have to be minimized; and ensuring the safety of tip areas primarily to avoid the machine falling into the orepass.
**Ventilation**

It is critical to have well ventilated workings to meet the standards required for operating diesel equipment underground. These standards must provide for adequate air quantities and in this respect there are specific parameters to be adhered to; a need to maintain good ventilation conditions where LHD’s have to load; to control dust.

### 2.22 Organisation and Management

Best management organisational practice for trackless mining operations, in the opinion of KAR, provides for all disciplines, including engineering, to report directly to the senior manager in charge of the shaft or project. Typically the classic structure can be seen in **Figure 9**. This structure was set down by KAR in 1986, before TM3 operations commenced at the H.J.Joel Gold Mine. In this organogram there would be included a project mining engineer to co-ordinate all technical services and also the mechanical equipment supervisor, both reportable to the project manager; see revised organogram in **Figure 10**.
The Project Manager is the
Manager in charge of operations. The
Production Manager is his deputy.