MANDELA MINING PRECINCT
MINDS FOR MINES

Milestone Progress Report (DRAFT 01)		
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Milestone Progress Report	WP 7.7: Final report, electronic safety logbook development.	
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1 EXECUTIVE SUMMARY

The scope of this final project report (LoCM Work-package 7.7) has focussed on the provision of an overview of the outcomes and objectives of the initiative to define a solution concept for the establishment of an electronic underground safety data recording capability. The shift-supervisor (boss) plays a key role as a data-capturer and user of this capability as they are responsible for the legal compliance of the key daily, weekly and monthly recorded safety data.

The recording of the legal duties and in many cases mine standard controls are currently captured in the manual "ink-based" logbooks. The limitation of people having access to the logbook safety data, provide limitations to line safety managers to make effective in-time decisions. Shift-supervisors, as key daily recorders of safety data, often do not record data correctly, which leads to inaccurate reflection of the real situation. It was shown that the future adoption of electronic safety recording capabilities by shift-supervisors, could largely solve the often non-compliant status of mine safety logbooks.

During the course of the research work, it was indicated that local capable and mature electronic logbook technology suppliers are available to the South African mining industry. Three suitable vendors have been identified with product solution systems already adopted by mining operations, but mostly available on PC-based computer systems. The recent emergence of tablet-based safety recording solutions have provided opportunities for shift-supervisors to now record safety data on a mobile device at their underground workplace locations.

The research has indicated that some of the vendors have already ported their safety solutions onto mobile tablet platforms while others are in the process of doing so. One vendor has been identified that has completed the software solution porting process to a tablet platform. While two of the vendors have been identified which has progressed to the final stages of their software porting development process. It is estimated that their development process could be completed in the next three months.

This development now provides the opportunity to demonstrate electronic safety solutions in test-mine pilot settings to mine operators, a development that could contribute to current mine safety compliance challenges.

2 AIM OF RESEARCH PROGRAMME

This research programme has focussed on the definition of requirements and evaluation of possible software pilot solutions for an electronic safety logbook data capturing capability for underground use by shift-supervisors. The objective was to suggest solutions for the transformation of the current manual best practices of recording safety data. The hypothesis for a proposed electronic capturing capability which shall ease the burden of the application of legal compliance practices, which is mostly the responsibility of shift-supervisors.

2.1 Aim of this particular milestone

a. This work-package (WP7.7) milestone: *Final report, electronic safety logbook development* , has focussed on the following:

- The provision of an overview of the research work performed by the various work packages during the research project;
- The provision of an overview on the availability of electronic safety recording technologies to the mining industry;
- The provision of an overview of the compliance to safety logbook electronic recording requirements identified during mining industry work-sessions;
- A reflection on the advantages of safety data recording processes to the mining industry.

2.2 Definitions

ARCHITECTURE
A system architecture is the conceptual model that defines the structure, behaviour, and more views of a system. An architecture description is a formal description and representation of a system, organized in a way that supports reasoning about the structures and behaviours of the system.

CAPABILITY
The measure of the ability of an organisation to achieve its objectives, especially in relation to its overall mission and vision.

CONOPS
The Concept of Operations (CONOPS) describes the conceptual solution approach towards achieving a capability. The CONOPS communicates the conceptual solution within the capability development team or organisation, to external and internal stakeholders.

FUNCTIONAL ARCHITECTURE
A Functional Architecture is an architectural model that identifies system function and their interactions. It defines how the functions will operate together to perform the system mission(s). Generally, more than one architecture can satisfy the requirements.

SAFETY AND SECURITY
Safety is the condition of being protected from harm or other non-desirable outcomes, caused by non-intentional failure. Security is the condition of being protected from harm or other non-desirable outcomes caused by intentional human actions or human behaviour.

PRODUCT
A physical or logical object that exhibits behaviour to change its environment.

NEED
Something that can be achieved by the realisation of requirements in products

USER REQUIREMENTS
An externally visible characteristic to be possessed by a product

USCS Node
An Underground Stope Communications System (USCS) node is an intelligent mesh capable network communications device that could be used in a mobile state, as part of the miner's wearable kit, or statically installed in the mine as part of the permanent communications infra-structure.

SYSTEM REQUIREMENTS
Characteristic of a product component for the product to be able to satisfy its user requirements.

TEST
Check to exercise a product component to confirm its behaviour or structure

VERIFICATION
Check that an internal characteristic of a product component is as required

VALIDATION
Check that an externally visible product characteristic is as required.

2.3 Abbreviations

CONOPS	Concept of Operations
FC	Functional Capability
DID	Data Item Description
GDP	Gross Domestic Product
LOS	Line of Sight
MTBF	Mean Time Between Failures
MTBcF	Mean Time Between Critical Failures
NLOS	Non Line Of Sight
SRS	System Requirements Specification
USCS	Underground Stope Communication System

2.4 Overview of project

The research work was initiated by the establishment of a research stakeholder group, which comprised of mining safety practitioners and managers from the mining industry, and industry suppliers of software solutions to the mining industry. During the research period stakeholder work sessions were conducted. Some of the key stakeholder group consensus findings were:

- The research group stakeholders were in consensus that a definite requirement exists for the establishment and adoption of an electronic safety data recording system;
- There are current legal constraints in the Mine, Health and Safety Act 29 of 1996, hence the suggestion that a review of the Act would enable the adoption of possible future electronic safety recording technologies. The rationale for this suggestion is that the law still contains regulations that supports only manual paper-based recording practices, and could be interpreted as if electronic-based recording systems are considered to be excluded. As an example, regulations stipulated in paragraphs 2.15.6 and 2.15.7 alludes to the legal requirement(s) that logbook records could only be recorded and approved manually, on paper and ink, e.g.

2.15.6 Each shift boss shall, during or at the conclusion of his shift, record in ink in his logbook-

(a) the designation of every *working place* and other workings inspected by him during his shift;

(b) particulars of any unsatisfactory condition of working places, travelling ways or other workings in his section as found by him or reported to him by a ganger or miner or any other person, especially as regards ventilation and dust, the presence of harmful gases, the state of the hanging wall, footwall and sides, sanitation and generally so far as safety and *health* of persons are concerned;

2.15.7 Such records shall be examined and countersigned by the manager or the mine overseer at least once every day and shall be open to inspection at all reasonable hours by any person employed in the workings of the said mine.

Figure 1: Paragraphs 2.15.6 and 2.15.7 text extraction from Act 29 of 1996

- There is a definite need for a future electronic safety logbook data recording capability, mostly to be used by shift-supervisors ("shift-bosses") in an underground setting;
- Current safety logbooks contain unnecessary, not legally required, production process related data, which often leads to mine stoppages when audited by inspectors. The stakeholder group suggests that future safety logbooks should be re-organised to only contain legally required safety data, and that operational process data should be recorded, separately as part of the operational management effort. A clear separation between safety data and operational process management data is suggested.
  In summary, an outdated, manually operated safety data recording and management system, which is labour intensive and error prone (Figure 2) was identified as a key challenge to address.

Figure 2: Outdated safety data recording and management process

2.5 Main Milestone deliverables

2.5.1 MS 2 - DMR business & technical requirements analysis

The aim of Milestone 2 (MS 2) was the analyses and collation of the requirements elicited during the three industry work-sessions. The final requirements were then formulated in a requirements specification which would be suitable to be used to for the development of a solution.

Some of the key findings which emerged during the requirements elicitation sessions were:

a. There are, broadly categorised, two types of South-African gold and platinum mines. The "older" type mines with limited underground ICT infrastructure, and "newer" type mines with well-established sub-surface ICT infrastructure. The implementation approach will hence be different, and the adoption strategy for "older" and "newer" mines, will have to be adapted to each mine's specific sub-surface ICT infra-structure.

b. The development requirements for an electronic safety capturing capability can be defined to be usable in older and newer capable mines. It would hence be possible to have a mobile recording tablet solution, which could be software configurable to operate in "older" or "newer" types of mines.

2.5.2 MS 3 – Feasibility and trade-off study

The aim of Milestone 3 (MS 3) was to identify the key feasible interventions that would implement the capabilities to improve on the shift-supervisor's current manual safety data recording practices. A market scan was performed with the aim of establishing the availability of capable South African OEM suppliers, that could in future, be available to develop an electronic safety recording capability for mines.

Some of the key findings identified during this phase were:

a. The current high occurrence of issuing Section 54 and 55 notices to mining companies, leads to substantial financial losses that could not be recovered during the rest of a financial operating year. Interventions are hence urgently required to substantially reduce the instances of mine stoppages;
b. The availability of shift bosses, to be at the work-place for a full shift are currently substantially reduced by the paper-bases recording practices. Shift-supervisors have to record safety data in their note-books, and then move to the surface to transfer the data onto paper-based logbooks. The data then also needs to be typed into an electronic database. All these manual required operations requires from the shift supervisor to travel back to the surface after the manual recording process has been concluded underground. This cause limited availability to the shift-supervisor to full-full his/her oversite and advisory role at the work-place;
c. The implementation of an electronic recording capability could reduce the probability of mine stoppages substantially. If the typical causes of mine stoppages are related to the capability interventions of a future electronic recording capability, it illustrates that improvements could be achieved on the majority of stoppage causes.
d. It was recommended that skilled and willing OEM suppliers should be identified to participate in the development of a pilot, tablet-based solution to demonstrate the capabilities required to record sub-surface safety data in an electronic format, for possible demonstration at a test-mine site.

2.5.3 MS4 – Solution system concept definition and criteria

The aim of Milestone (MS 4) were:

- to identify realistic and relevant underground work-area mining use cases which could be used in future as baseline requirements inputs on how the shift-supervisor would use an electronic recording capability to capture safety data in an electronic format, and;
- to analyse the shift-supervisor use-cases with the aim to derive the functional requirements from them, in order to define a physical electronic recording solution which could be used in future to develop or procure a practical solution to be evaluated in a pilot context.

Some of the key findings identified during this phase were:

a. The requirements for three solution systems have been defined:
   - Data to be recorded underground by means of a table device and then submitted to a database at the surface (older mines);
   - Data could also be recorded underground and submitted underground at specific via Wi-Fi router-spots, available at strategic spots in newer mines;
   - Thirdly, a future use-case where a full stope-communication system is available has been identified. In this case the shift-supervisor would be able to record and upload data from any position in the stope, as the communication capability would be available in any position in the stope area.
b. It was concluded that due the fact that mature and available South African OEM vendors are available and willing to participate, it would be possible to

demonstrate, in a pilot setting, the advantages of electronic recording of underground safety data, by shift supervisors.

2.5.4 MS6 – Test of Reporting Device

The aims of Milestone 6 (MS 6) were:

• The identification of three mature and capable solution vendors, which do have a track-record in the development of solutions for recording and analysis of mining safety and logbook data;

• To obtain typical development and deployment cost structures of these identified vendors for the adaptation of their product solutions for underground recording of safety data by a typical shift-supervisor (boss) role;

• To evaluate the capabilities of the identified vendor's solution systems for suitability and adoption by mining safety operation role-players. The objective is not to compare vendor solutions, but rather to explore the effectiveness of the current capabilities offered to the mine safety practitioner's community with the focus of meeting the criteria and requirements.

Some of the key findings identified during this phase were:

a. Each of the three vendor's software solutions demonstrated the capability to capture and process the legally required safety parameters, and vendors do attempt to comply with safety legislation as close as possible;
b. The implementation of the safety logbook software solutions to run on mobile devices are in different stages of development. The Triple M Mining vendor-solution can run on an Android Operation System (OS) mobile tablet device, which links back to a back-end server system. The Pivot Systems vendor-solution can currently run on Windows-based (OS) computers and tablet devices, and the vendors is currently porting and testing the software to run on an Android-based tablet device, to be released soon. Pivot Systems will issue an Android (OS) version soon on tablet. Mine-ware has indicated that they are also in the process to develop a mobile tablet based solution. The release of this solution could be available in a few months.
c. The availability and capability of locally developed electronic logbook systems have reached a suitably level of maturity, which make it suitable to be adopted by local mines. The porting and implementation of electronic logbook solution software onto mobile tablet devices, have in some vendor cases been completed, and in active use at their mining client sites. In other cases the porting and implementation process would be completed in the next three months.
d. The three vendor solutions evaluated could all be adapted and configured to comply with each mine's individual logbook layout format. Client mines should consider the technical and cost implications when selecting an electronic logbook solution, as integration with its existing operational management software would be required for seamless dataflow between the solutions.

2.6 Availability of technology solution options

During the stakeholder workgroup sessions, three mature and capable solution providers have been identified which could provide possible future solutions to the mining industry. The three vendors namely; Mine-ware, Pivot Systems and Triple M (MMM) technologies have all already established their own mining user clients, which have already adopted some of their operational management software solutions, which all have interfaces to a possible electronic logbook safety recording capability.

It was found that all the vendors (Figure 3) were already engaged in their respective in-house development processes. Figure 3 depicts the relative current progress of each vendor in the establishment of a mobile, tablet-based electronic solution for underground adoption.

During the research work-sessions and visits to vendor's sites, it was discovered that Triple M Mining has already progressed in their development process to a configured electronic safety logbook solution, already available on a mobile tablet device. Pivot Systems is currently in the testing phase of their tablet-based solution development, to be available in 6 weeks, while Mine ware's tablet solution development process could be concluded in the next three months.

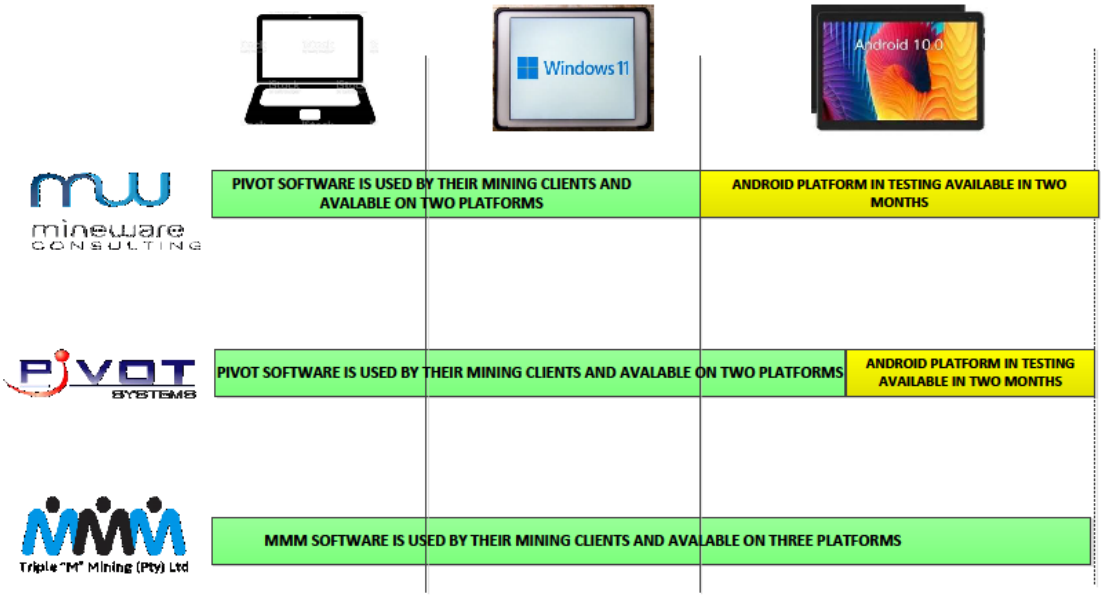

Figure 3: Relative vendor solution development progress

2.7 Typical compliance

Laboratory testing of the various vendor's solutions recently at the CSIR, was conducted mainly to demonstrate the current electronic logbook solution capabilities. The electronic safety logbook parameter requirements, as defined by the research work-group (Figure 7), was used as test requirements baseline.

Figure 4: **Pivot Systems set up their electronic logbook solution (laptop-platform), at the CSIR, for demonstration and evaluation**

Figure 5: **Representatives of Triple M Mining set up their electronic logbook solution (Tablet platform), at the CSIR, for demonstration and evaluation**

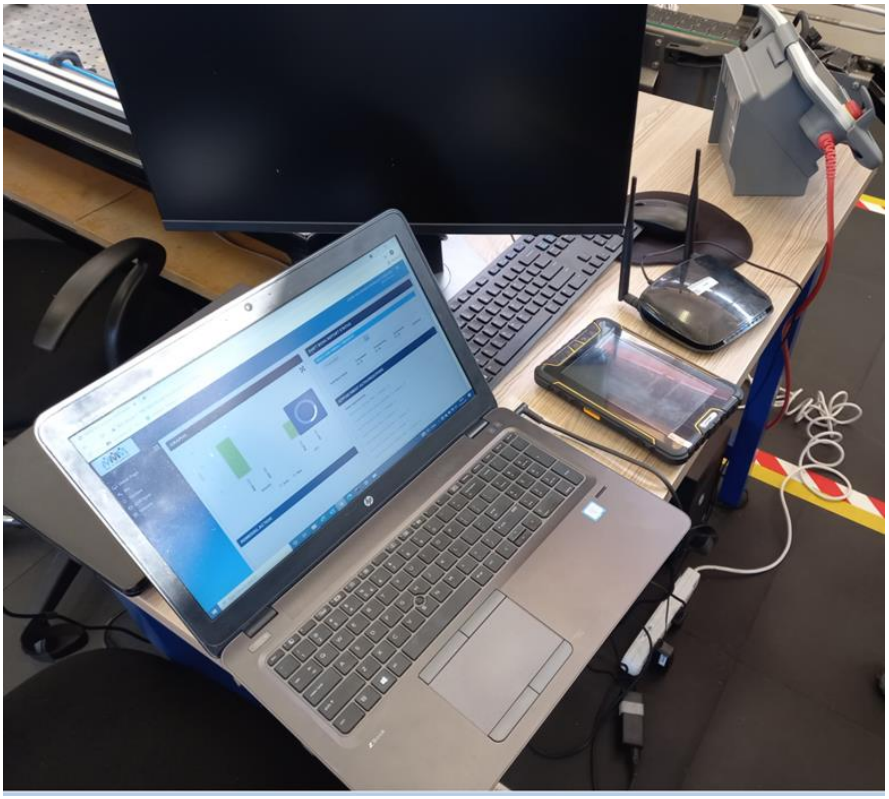

Figure 6: Typical tablet-based solution test-setup during the Triple M Mining demonstration and test

During the CSIR laboratory demonstration and test set-up evaluations of the various solutions, it was clear that the level of functionality and compliance to the functional parameter requirements of the electronic logbook parameter was excellent. There is full compliance of all vendors to the legally mandated logbook parameters (Figure 7) of the daily, weekly and monthly data recording requirements.

There is however, differences in how the software Graphic User Interfaces are designed, which results in different operator experiences. This is mainly due to the fact that the software was all developed in close collaboration with mining client's requirements, hence a different evolvement of the software solutions.

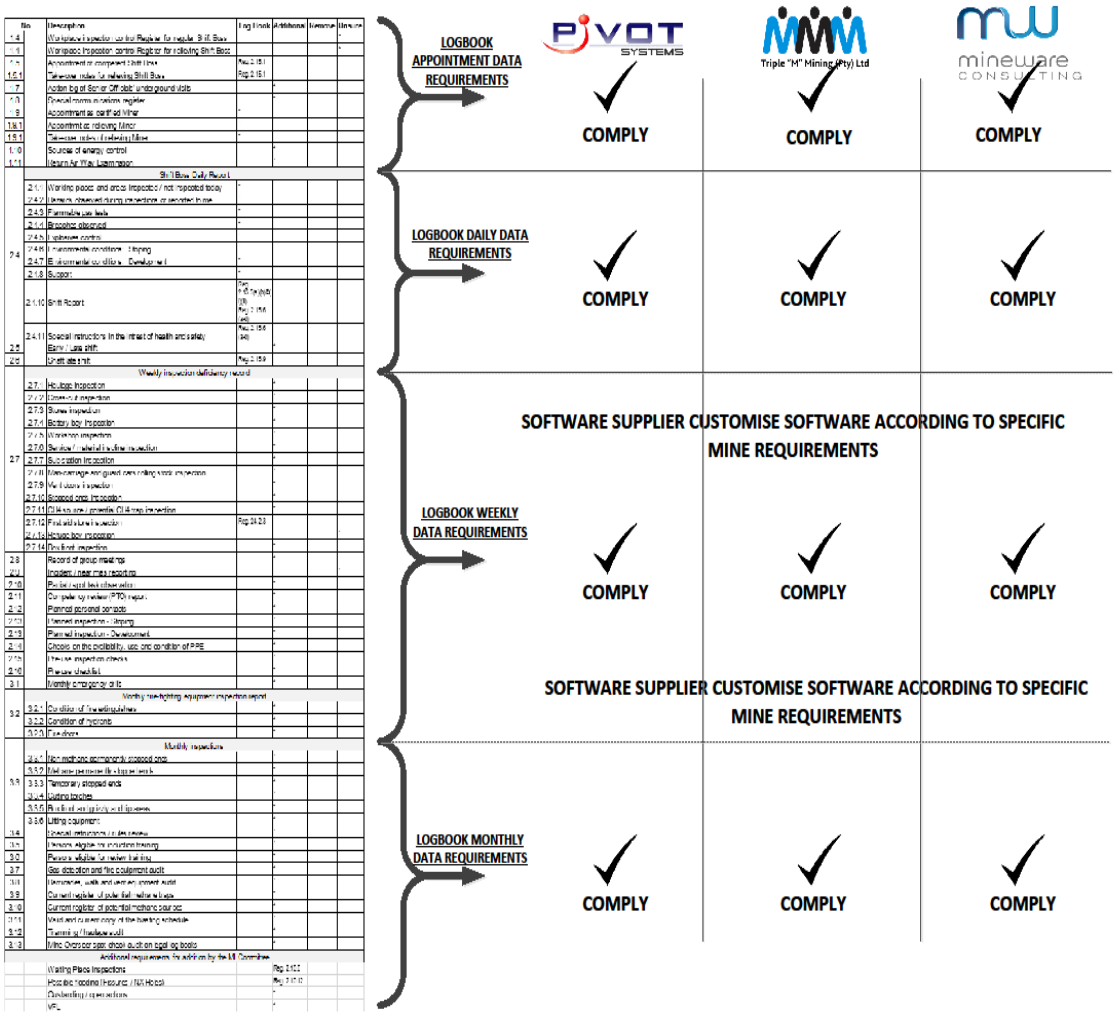

Figure 7: Electronic logbook test data requirements compliance

2.8 Typical implementation architecture

The future implementation of electronic safety data recording tablets with shift-supervisors will require the issuing of tablet devices to shift-supervisors (Figure 8). The typical implementation architecture of the required integration information system is depicted in Figure 9. Vendors have indicated that the implementation of a solution is typically a three-month process, consisting of the following implementation steps:

- Month 1 : Analyse, document and review the specific safety management requirements of the specific mine;
- Month 2: Establish required infra-structure, and implement a pilot site, and mentor the client in using the software. Training of shift-supervisors occur during this stage;
- Month 3: Full operational launch of the solution, while supporting the client

Figure 8: **Tablets shall have to be issued to shift-supervisors with WiFi link capabilities to download data at suitable spots**

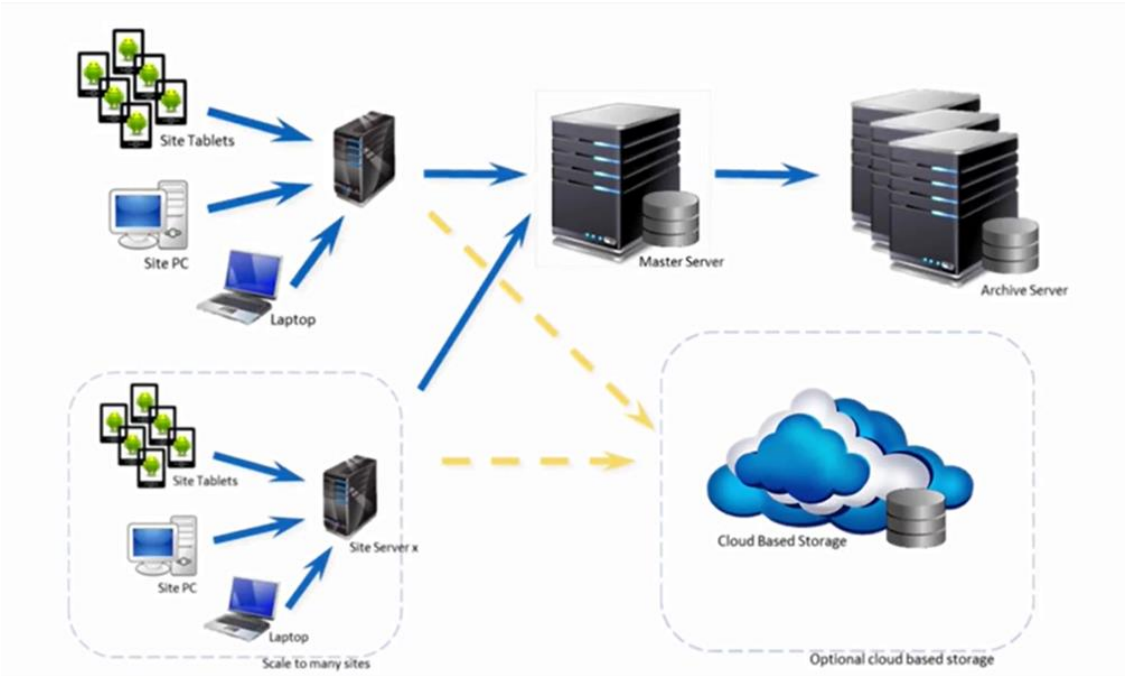

Figure 9: **Typical required information system implementation architecture**

2.9 Advantages of electronic safety data recording capabilities

In the pursuit of improving safety standards over the past few years, the mining industry has made significant progress in improving overall safety records. The improvement in manual safety management and safety data recording processes was improved substantially. However, the daily work pressure on shift supervisors often cause that data is collected in-correctly or not in compliance with legislation. During the research work-group sessions it became evident that over the past few years, there has been an increasing awareness, that to further improve on legal compliance regulations, organisational behavioural change on executive management, operational management and on underground miner overseer practitioner levels will have to be implemented. Organisational behaviour change is often driven by the near-real-time availability of operational data to the various organisational layers, as this informs managers and practitioner's in-time to change behaviour to drive change. This is would be the value of electronic recording and reporting of underground safety data would contribute towards driving the change in safety management behaviour. The spin-off un-intended positive consequences will be less mine-stoppages, less injuries, less unscheduled maintenance work and increased production.
The projected advantages at the various organisational levels are explored in the following paragraphs.

2.9.1 Executive management level

- **Safety Improvement** – Mine safety and general production data recorded and processed in near-real time and published in daily management reports, shall lead to an increased management situational awareness which results in the pro-active identification of trends and incidents which could to be used as preventative actions before a significant unwanted event occurs.

- **Pro-active Decision Making** – Automated aggregation of safety data and conversion of data into automatically generated safety reports increases the value of reporting as the data is immediate, up-to-date and accurate. This has the additional advantage of reducing pressure on management by providing up-to-date accurately collated data facilitating pro-active decision-making which has been identified as key to the survival of the mining industry in South Africa. The near-real time availability of management data also reveal certain employee behavioural patterns over a period which enables pro-active decision making, i.e depicted in Figure 10. This graphical depiction collates the effort of a shift-supervisor to perform a certain data-recording activity on his tablet. For the majority of the month between dates 1st to 20th the task do not exceed 10 minutes to complete. Between the 21st and 25th day of the month the task takes 58% more to complete. This indicates an inconsistency that should be investigated by management to discover the rationale for this tendency.

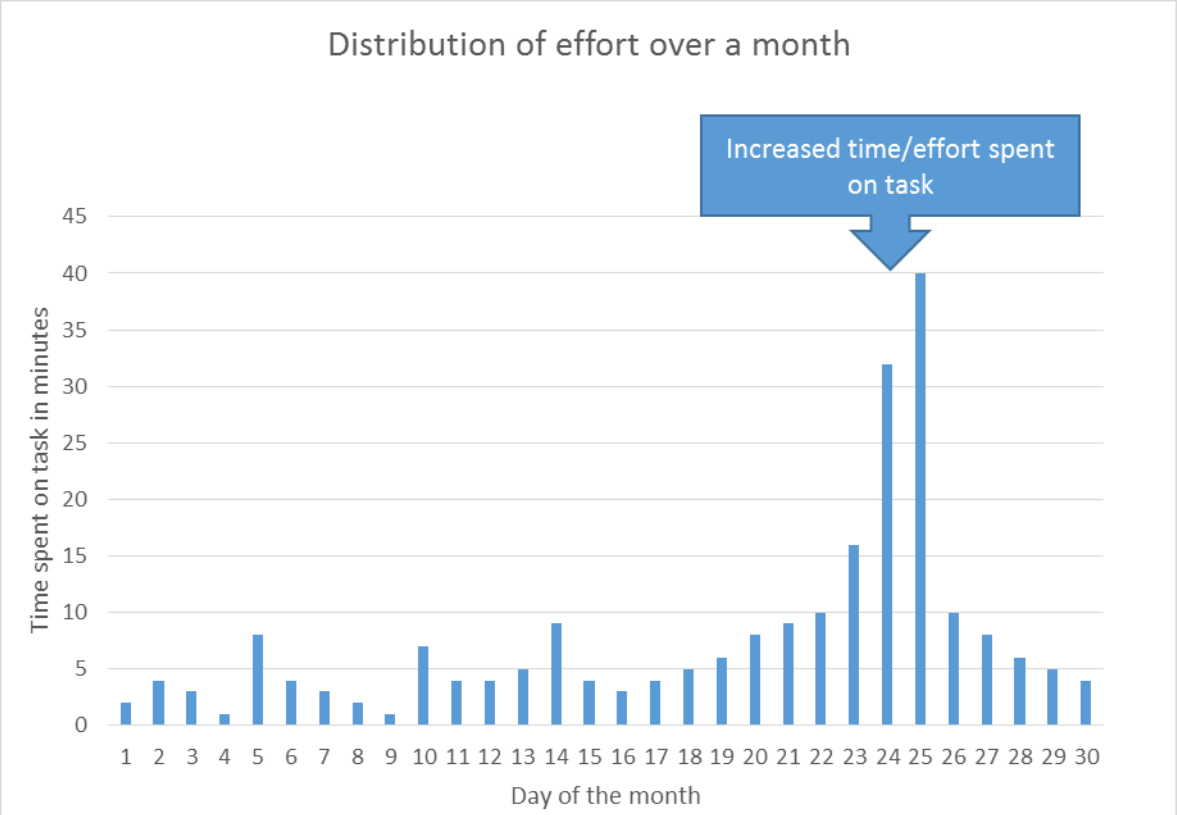

Figure 10: **Pro-active detection of the distribution of time and effort over a monthly period**

- **Integrated Systems** - The process of manually aggregating safety data spreadsheets based on data from different parts of the mine operation, and converting these into meaningful reports, is inherently cumbersome and inefficient and has a significant element of interpretation by the shift supervisors in their role as data capturers. This leads to incorrect decision making due to poor and often subjective data. An electronic recording technologies solution provides a high level of automated data integration resulting in the ability to generate real time, automated safety reporting for improved in-time decision making.

- **Performance Management** – Real-time safety data readily availability results in the in-time identification of potential areas of safety non-performance or where performance improvement is required.
  The availability of safety data, can also reveal possible training needs of shift-supervisors. Figure 11 depicts a typical data quality entry distribution for shift-supervisors. Some supervisors do capture their data in a "slash and dash" way, alluding to the possibility that data is captured too quickly, hence not sufficiently accurate and complete, while other supervisors capture data in a very slow way, alluding to the possibility that the do not have the required skill level to perform their task efficiently. This could indicate that training would be required to rectify the problem.

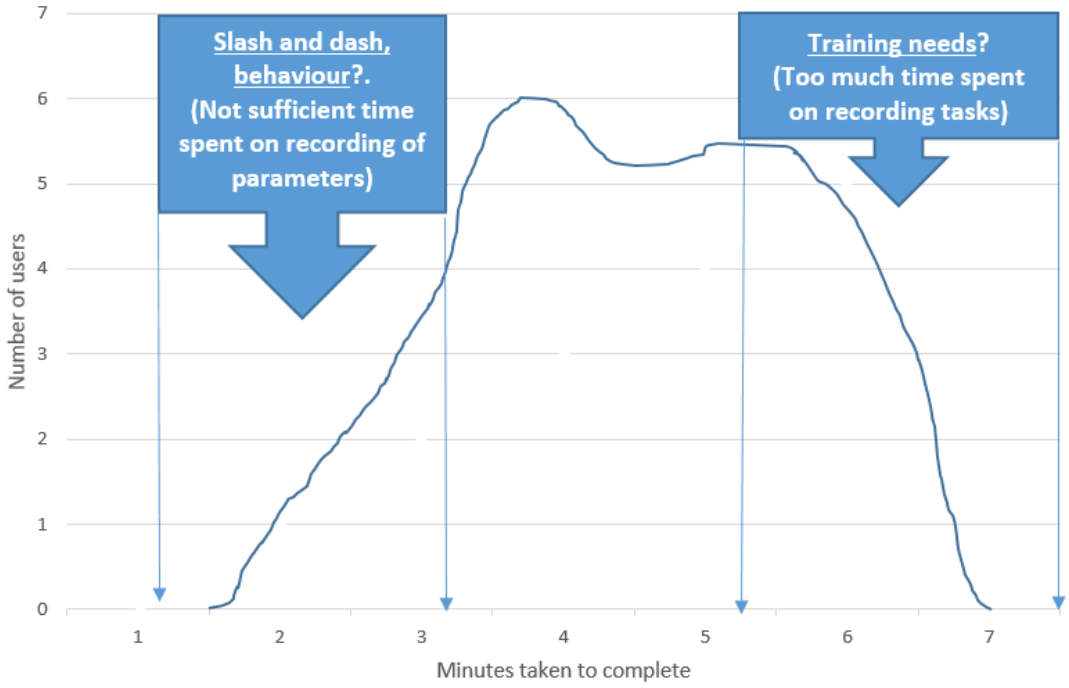

Figure 11: Data quality entry distribution performance

2.9.2 General mine safety management

- ***Safety Improvements***
  - i. The increased real-time availability and visibility of shift-supervisor recorded safety data across all shifts shall allow for proactive and effective safety management, with a low probability requirement for unplanned interventions ("no-surprises");
  - ii. The near-real time processing of safety data shall provide adequate management feedback and the automated system improves feedback mechanisms linking non-compliance to workplaces and incorrect behaviour of employees and safety instructions. By being able to quickly and efficiently know which instructions/works orders are not being closed out and tracking any overdue work which potentially has life threatening consequences, the electronic solution will have a direct impact on safety.
- ***Risk Reduction***
  - i. Internal organisational awareness of safety non-compliances shall be allowing for preventative steps to be taken by mine employees to resolve, reducing un-intentional safety stops;
  - ii. Complete, up-to-date, accurate and tamper proof safety record keeping available at all times during an operational shift;
- ***Integrated Systems***

An electronic safety recording capability shall have the potential to provide increasingly integrated mine operational information to other mine operational "departments" as their adoption in the use of digital devices for data logging and reporting is used. This will make tracking of other mine operational trends which may be emerging easier to detect in-time for the implementation of pro-active interventions.

Cost Management
Reduction of manual time consuming and costly efforts for data capturing and auditing of multiple, disparate paper-based systems.

2.9.3 Mine overseer/ Captain

- ***Pro-active management advantages***

i. The Mine Captain has real time immediate access and monitoring of reports and records remotely, without having to wait for the manual recorded safety data is available on the surface, decisions can be made in time;
ii. The Mine Captain can send real time instructions electronically with proof of acknowledgement by the affected shift-supervisor;

- ***No-Surprises*** - Automated identification of complete or incomplete safety documentation reduces the burden on the team to identify where they are not compliant;

Collating manual information
The process of manually aggregating spreadsheets based on safety data from different levels and parts of the mine, and the conversion of these into meaningful reports, is inherently cumbersome and inefficient and has a big element of different interpretations by the data capturers (shift-supervisors), which leads to incorrect decision making due to poor and often subjective data.

2.9.4 Shift-supervisor ("Shiftboss") – pro-actively changing behaviour

- ***Self-Auditing*** – An electronic safety recording capability allows a shift-supervisor self-checking functionalities, so incomplete documentation or checks not yet completed are identified and addressed before submission , hence reducing risk of being in violation of safety legislation;
- ***Integrated Communication and collaboration*** – Shift to Shift digital communication capabilities would be instantaneous, recorded digitally and available historically. Shift-supervisor collaboration with fellow miners to collate safety data enhances accuracy;

Figure 12: **Electronic recording capabilities enable Shift supervisors to collate voice, visual and text inputs from colleques to improve data accuracy**

- ***Reminders*** – Electronic recording systems do provide prompts and reminders to shift-supervisors, to ensure work is completed on time and correctly. The pre-prepared menu, ensures the documentation required will always be up to date;
- ***Portability*** – The safety records, "paperwork" , travels with you and allows the immediate entry and record keeping;
- ***Constant change*** – DMR and Mining standards change frequently and a digital system allows modification and roll out within a matter of days, with checklists and forms updated flexibly and reliably.
- ***Timesaving*** – Using "dead time" to complete paperwork and documentation
- ***Solving some of the general paper-based safety logbook challenges –*** Electronic recording of safety data supports the shift-supervisor to record data in a correct and complete format, supporting legal compliance. Some of the paper-based recording challenges, w.r.t. electronic recording capabilities are summarised in Table 1.

✗ physical loss(missing)	digital storage (zero data loss)
✗ damaged or unusable	data redundancy and physical backup
✗ often unable to effectively retrieve and use during enquiries	real time web based queries and retrieval
✗ tampering - after an incident it's been known the logbook is updated (or re-created) to reflect in favour of parties	digitally and physically secure, tamper proof
✗ Incorrectly filled in or forms incomplete	wizard driven significantly reducing errors
✗ limited physical space (hard to understand short hand)	unlimited space for detailed notes
✗ Inconsistent across shift supervisors/mine overseers	forms driven for consistency and immediate error correction
✗ unclear language, illegible handwriting and signatures	Keyboard text
✗ human error due to retrospective entry (forgetting)	portable immediate access, photography and recording
✗ time consuming manual process resulting in impact on production due to complexity/volume	reduced time due it usability and portability
✗ zero system integration	highly integration capable, reports driven
✗ zero dashboard view	customised dashboards

Table 1: Summary of typical manual safety logbook challenges w.r.t electronic logbook solutions

3 RESEARCH FINDINGS

3.1 Research Findings

3.1.1 Research Outcome 1

There are currently multiple vendors available in the RSA marketplace that has the capability to supply, support and train mine operators in the adoption and use of electronic recording technologies for application in the safety management domain. Each mine usually has their own unique safety logbook set of requirements, hence vendors usually has to customise the Graphic User Interface (GUI) to comply with each mine's operational conditions. Vendors also have the capability to compile and configure customised management safety reports, as usually required by mine operators.

3.1.2 Research Outcome 2:

Vendors of electronic safety data recording are currently in various stages of development w.r.t. the conversion and re-configuring of their solutions to run on mobile Android handheld devices. There are vendors that have already concluded their development, and in –use with their respective clients. Other vendors are currently in various stages of the testing phase, and should be available to the industry in a period not exceeding three months.

3.1.3 Research Outcome 3: Solution readiness

The current maturity of the safety recording solutions offered by the vendors are high, and can be adapted to specific mine requirements in short timescales not exceeding three months. The porting of software solutions to mobile tablet devices has been completed by one vendor, and is

available, while two vendors are currently in the software porting process, to be completed in the next three months.

4 CONCLUSIONS FROM MILESTONE

The needs for the mass adoption of electronic capturing of safety data by shift-supervisors, has been established, and the majority of mine safety management teams do realise the value of the technology. The capital expenditure of issuing tablets to shift-supervisors is currently still considered as an entry barrier for certain of the older mines that do not have established underground ICT capabilities yet. With the further reduction in the procurement prices of tablets available on the market, and the increasing realisation of the operational advantage of this capability, it is envisaged that the resistance to the adoption will crumble.
The typical safety software capability adoption phases and timescales for a mine shaft operation of 50 shift-supervisors, is depicted in Figure 14. During the first month, the vendor will typically elicit and analyse the specific client-mine's safety needs and requirements, train shift-supervisors and establish ICT infrastructure if required.

Once an understanding of the specific mine needs are well defined, the roll-out of the system will typically be done during the second month. It is important to note that the paper-based safety recording system is still maintained for at least a month, as this ensures continuation of the safety management effort, while technical problems are solved. During month three, the shift-supervisors will commence to use the electronic recording capability, under mentorship of the vendor. Issues and technical problems are solved at the workplace by the vendor to ensure smooth adoption is ensured.

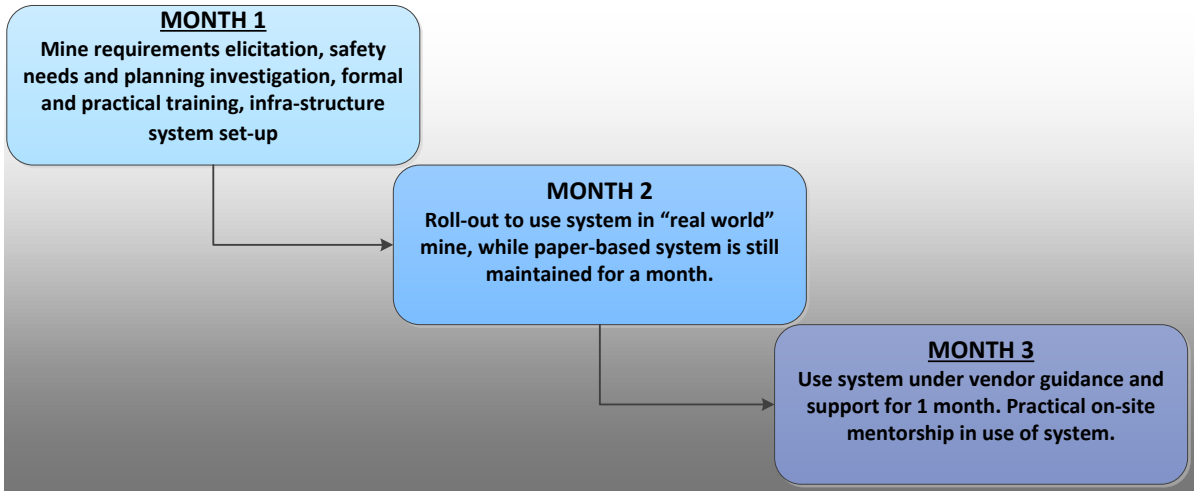

Figure 13: Typical adoption time-scale

The typical establishment and adoption costs for a mine-shaft operation with 50 shift-supervisors are depicted in Table 3. Three South-African vendors were approached to provide typical establishment costs, hence it is important that the vendor costs cannot be compared, as each vendor's safety software integrates with a wider mine operational management system, which is different in each case. The Table 3 costs do however provide an indication of typical establishment cost components which is useful. Table 3 do provide for the typical once-off cost drivers such as training fees (required by month 2) and applicable once-off fees. The monthly

operational licence fees of most vendors also include the maintenance fees, hence no additional maintenance fees are usually required.

Typical ad option costs for a NEW mine operation with 50 Shift-Supervisors, with established ICT infrastructure						
Vendor	**Typical once-off establishment cost**			**Typical monthly operational**		**Notes**
	Training (50) Shift-supervisors	**Once-off establishment**	**50 x Ruggadised Tablets**	**Mobile SW license**	**Safety SW License**	
1	R250 000		R15 000	R12 000	R150 000	Technical maintenance included in SW license fee.
2	R75 240	R125 000	R15 000	R11 000	R17 500	
3	R75 000		R15 000	R52 000	R128 073	

Table 2: Typical tablet and safety software establishment costs

[Assumption: The Table 1 assumption is for a new mine with established ICT infra-structure]

The adoption of electronic recording of safety data, has the advantage of improving the mine performance at three levels, firstly at the executive management level, where safety management can be done based on pro-active decision making, based on near-real-time availability of data, which enhances the KPI parameters of the mine, as the accurate operational data immediately identifies potential areas of non-performance or where performance improvement is required. On the operational management level, real mine safety improvements can be implemented as the increased situational awareness provide management visibility across all shifts allowing for effective management by exception. At the shift-supervisor level, the system allows for supervisor self-checking, as any documentation or checks not completed are quickly identified and addressed reducing risk of being in violation.

5 RECOMMENDATIONS

It is recommended, for a next research phase, to implement a practical pilot demonstration of tablet based safety data recording solutions in a test-mine context. This initiative shall showcase the capabilities to mining stakeholders to facilitate and expedite the adoption of these capabilities in underground applications.