A review of the role of the coal mine surveyor in South Africa

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Synopsis

This paper focuses on the role of the coal mine surveyor at the start of the 21st century. It demonstrates that surveyors must look beyond their legal appointment and pursue opportunities to add value at an operational or corporate level of the company. It also exposes the shortfall of statutory appointments in defining the surveyor's role in terms of key business drivers of the company. One such an opportunity is the potential role of the surveyor in mineral accounting and quality assurance to meet mine requirements, market specifications and standards pertaining to corporate governance and reporting. Finally, some thoughts are expressed on what can be done to elevate current practice to best practice and how to achieve this goal

Introduction

Coal mining is essentially driven by the movement of considerable volumes of earth material[1]. It is, therefore, understandable that tremendous emphasis is placed on efficiencies, availabilities, utilization and productivity of the equipment (fixed and mobile)[2] that support the movement of material and product along the mining value chain. To support improvement drives of this nature, best practices on maintenance management planning is being developed and implemented across the globe. This search for best practice will continue to play an increasingly important role in the future of industries that are heavily reliant on large earthmoving equipment, such as the surface mining environment. Financial modelling has become a major business factor and requires that these key performance indicators monitor and manage equipment cost by means of activity (or process).

The challenge in the mining industry to date has been to report actual costs at an activity or process level of the business. This reporting method is mainly due to the historical background of financial reporting structures that support costing models that are configured to report per responsibility within the organizational structure of the operation. Although still at an early stage in South Africa, large mining houses, through the use of enterprise resource planning systems[3], are now aligning their financial management reporting systems to support process costing that enables the business to compare key performance indicators (KPIs) per equipment type, using a common basis within the company.

Where do the above issues leave the coal mine surveyor and how is the role of the surveyor affected by these improvement initiatives at an operational level? Being smarter about the measuring per process type and the granularity and frequencies of measurements contributes to improving reporting on material handling efficiencies and material tracking per process cost. During opencast mining operations, the type of material moved, such as topsoil stripping, overburden, interburden or coal removal, is directly related to the type of equipment involved and measurement of material moved. These issues raise questions on business best practice for survey measurements in order to report against business drivers at an operational and corporate level of the business.

To arrive at these business best practices, a maturity journey has to be embarked upon within the survey environment. This maturity journey is achieved by, firstly, recording current individual mine practices and the extent to which these practices support the business drivers on measuring cost drivers

[1]Unlike high value metals such as gold and platinum, which are driven by grade rather than volume. This has a considerable impact on the role of the surveyor.
[2]Fixed equipment, such as conveyor belts and beneficiation plants, and mobile equipment, such as draglines, trucks, shovels and dozers.
[3]For example SAP.

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through thorough review sessions. These reviews of actual practice as measured against purpose will highlight current leading practices that support the business strategy and then, finally, implement and sustain, where necessary, leading and best practices across all operations through standard operating procedures by defining rules that support the overall business strategy. Such studies are not only important to the development of the coal mine surveying profession but will also add significant economic value to the coal industry in general. All coal mining stakeholders will, therefore, benefit as a result.

This paper briefly discusses the development of the role of the surveyor, both internationally and in South Africa. The intention is to explain what coal mine surveyors actually do today to develop a strategy towards practices that support the overall business imperatives. The emphasis is not so much on how they do it (the methods are governed by codes of practice and standard operating procedures, which are site specific) but on the main functions currently performed by them. The rules and principles governing the mine surveying profession are also highlighted. These are followed by a view of where the profession is heading[4].

Historical role of the mine surveyor

This section explains how the role of the mine surveyor evolved to date. The description is broad and applies not only to the role of the coal mine surveyor but also surveying in general. The Institute of Mine Surveyors of South Africa (IMSSA, 2005) adopted the definition of the International Society of Mine Surveying (ISM), which reads as follows:

'...[Mine surveying is a], branch of mining science and technology which includes all measurements, calculations and mapping which serve the purpose of ascertaining and documenting information at all stages, from prospecting to exploitation, and utilizing mineral deposits by both surface and underground workings...'

The principal activities of a mine surveyor are stated as follows:

- The interpretation of the geology...
- The ... management of mineral rights...
- The making, recording and calculation of mine surveying measurements, to provide the basis for the planning and control of mine workings to ensure economical and safe mining operations.

The above understanding of the role of the mine surveyor leads to two fundamental questions. The first question is: How did the definition for and principal activities of the mine surveyor change over time to arrive at the current understanding? The second question that arises is: Is this understanding reflective of the coal mine surveying industry today?

According to Linklater (2002), the original meaning of surveyor as it was first used in the literature in the early 1500s was derived from a combination of the French words *sur*, which means over, and *voir*, which means see. *Survoir* was then interpreted as oversee, which described the principal activity, namely to oversee property. In terms of this definition, the principal duties were as follows:

- Walking the lands to note property uses and tenants
- Drawing up official records and
- Calculating rents, duties, etc.

By about 1600, mapmaking was added to these duties. The addition of mapmaking raised the need for area calculations when land was exchanged for goods, cash or services.

As far as mine surveying is concerned, Agricola (1556) gave the first comprehensive discussion on surveying as applied to mining. He referred to the art of surveying, which involved the following activities during the mid 1500s[5]:

- Boundary and lease surveys, so that '... workmen may not encroach on other people's possessions...' (p. 129). Linked to lease surveys was the settling of disputes; '...The surveyor either himself settles the dispute between the owners, or by his art gives evidence to the judges...' (p. 145)
- Measurement of distance, solving of triangles and error propagation because '...surveying depends on the measuring of triangles...(and)...most particular care must be taken that we do not deviate at all from a correct measuring...' (p. 129) ... (and) carelessness into a slight error, this at the end will produce great errors' (p. 130). Setting-out and engineering surveys for mine health and safety were described as '...when a tunnel is being driven towards a shaft and does not yet reach it ...(and) ...neither the tunnel reaches to that point nor has the shaft been sunk to it... (p. 130) (and) ... since a tunnel, for every one hundred fathoms of length, rises in grade one fathom...' (p. 133)
- Area calculations were described as '... the surveyor employs his art when the owners of the mines desire to know how many fathoms of the intervening ground require to be dug...' (p. 130); and finally
- Mine economics for metal mines, '...to calculate the expenditure, in order that the owners of a metal-bearing mine may hasten the sinking of a shaft and the excavation of the metal...' (p. 130).

The most extensive publication on the role of the mine surveyor in South Africa was done by Dennis (1977), who listed the functions of certificated mine surveyors as follows[6]:

- Surveys for the preparation of underground and surface statutory mine plans, indicating mine boundaries
- Engineering surveys for mine planning and design, which included surface protection and preparation of plans for undermining permissions
- Area measurement and volume calculations, both underground and on surface

[4]The views expressed are those of the authors, which views are personal, based on experience and are reflective of the current coal industry in South Africa. Although some of the issues are also applicable to other mines, the emphasis is on the role of the coal mine surveyor.

[5]The reader should note that mine surveying dates much further back than the 1500s. In a footnote to Agricola's discussion, it is mentioned that the Chinese had developed accurate surveying instrumentation before the Christian era. The oldest mining map in the world is the Turin papyrus map showing certain gold mines between the Nile and the Red Sea, which dates to about 1300 BC.

[6]The order was changed so that the functions could be directly compared with those described by Agricola.

- Mine valuation, which included sampling, mapping geological features during sampling, grade/content calculations, grade control, provision of information on profitability to mine management, development of life of mine plans and reserve estimation
- Dennis finally discussed the important duty of keeping the mine manager informed by observing general health, safety and economic conditions at mines. Such observations led to wide-ranging instructions from mine management, which could be traced right back to the original French definition of surveying.

By comparing the earliest understanding of mine surveying with what Dennis observed in 1977, one can conclude that, apart from reserve estimation on gold mines, the role of the mine surveyor did not fundamentally change from medieval times to the end of the 20th century.

Rules and principles of mine surveying in South Africa

The rules and principles currently affecting mine survey practices are laws and regulations, qualifications for appointment in responsible positions, professional registration, and national and international standards. This section demonstrates that the role of the mine surveyor in South Africa traditionally has been dominated by legal, and not business, requirements.

In South Africa, the rules governing the functions and duties of mine surveyors are contained in the two main statutory acts governing the minerals sector, namely the Mine Health and Safety Act (MHSA) 29 of 1996 and the Mineral and Petroleum Resources Development Act (MPRDA) 50 of 2002, together with their secondary legislation and regulations. Mine surveyors have specific duties in terms of these two acts, especially the MHSA. In terms of the MHSA, mine surveyors, as employees, must assist employers with general health and safety matters[7] required for ensuring safe operations. More specific mine survey duties appear in Chapters 14 and 17 of the regulations[8]. Chapter 14 is concerned with protection of the surface and workings, ingress of water or other fluid material into workings and risks, such as rock falls, subsidence, cavities and collapse of surface structures at mines. The role of the mine surveyor includes the surveying, monitoring and reporting of these risks to management. Chapter 17 deals with specific statutory duties of mine surveyors with respect to the following[9]:

- The appointment of the competent surveyor to take charge of mine surveying at a mine
- General practice relating to accuracy and standards for field surveys, projection and survey systems, processing of survey data and mapping at mines
- Safety precautions, procedures and reporting of risks requiring survey input[10]
- The detailed requirements for the compilation, updating and submission of statutory mine plans and departmental copies and
- The survey issues relating to mine closure.

The role of the mine surveyor in terms of the MPRDA will vary from company to company and the qualifications of the surveyor. The primary role is the preparation and signature of maps, plans and diagrams when applying for mining rights and permissions and the registration of such rights. Section 3 of the Regulations[11] to the Mining Titles Registration Act (MTRA) 24 of 2003 defines surveyor as a person registered at PLATO[12] in the category of either Professional Land Surveyor or Professional Mine Surveyor[13]. Chapter IV of the MTRA deals with the requirements for diagrams and plans, which must accompany applications for rights, permissions, permits and reservations. All plans must be signed and certified by a qualified (registered in the professional category) surveyor. In contrast, the qualifications for mine surveyors for appointment as competent person in charge of mine surveying in terms of the MHSA[14] are either a Government Certificate of Competency in Mine Surveying or an NQF Level 6 qualification in Mine Survey and Mapping (as accredited by PLATO)[15].

The discussion in the previous paragraph illustrates the importance of legal requirements in defining the role of the mine surveyor today. This paragraph demonstrates that in addition to legal compliance issues, national and international standards are increasingly playing an important role in what is expected from surveyors today. The mining industry in South Africa has undergone dramatic changes in the last two decades of the 20th century. Where mining companies had national assets in 1977, today they are international with assets around the globe. Some mining companies, for example BHP Billiton, are no longer operated from a head office in South Africa but from a foreign country with different rules and standards[16]. International standards are applicable only to South African surveyors working for multinational mining companies, e.g. BHP Billiton, the Anglo group of companies and Goldfields. These multinationals have operations in different parts of the world and have, or are in the process of, standardizing mine survey practices across the group through international communities of practices and networks using guideline documents. These documents broadly define the role of the mine surveyor and the standards for functions and, sometimes, individual duties. If a company's assets are all located in the same country, national standards apply. These standards can be more detailed because the laws, regulations, qualifications and professional registration are the same for all operations.

[7]There are several sections in the MHSA that are applicable in this respect; these can be found in the object of the Act and Sections 2, 7–11, 22–23, 54 and 86.
[8]*Government Gazette* 26963 of 12 November 2004.
[9]The reader should note that this is a very brief summary of the statutory role of the mine surveyor. More details are available from Chapter 17.
[10]For example, working faces, abandoned faces, safety pillars, boundary pillars, cavities, restricted areas, accumulations of water, fluid material or gas, surface structures requiring protection and the monitoring of movement (underground and on surface).
[11]*Regulation Gazette* no. 7965, vol. 467, 14/05/2004 No 26352.
[12]The South African Council for Professional and Technical Surveyors.
[13]See requirements of (PLATO) Act 40 of 1984, as amended.
[14]As per definition in Chapter 17 of the Regulations.
[15]For the latest developments and thinking on the requirements of and qualifications of surveyors, see the Surveying Profession Bill of 2005.
[16]These rules and standards include national health and safety regulations, mineral development regulations, reporting standards, listing requirements and professional technical procedures.

However, even when all operations are national, care must be taken not to be too prescriptive when deriving standards for individual duties because each operation poses different demands to management and its expectations of what is required from the mine survey department.

From the above, it is clear that the role of the mine surveyor has been principally driven by legal requirements. Over time, professional registration became an issue. The result is that surveyors today view their legal appointment as the principal measure of performance. In the meantime, the business has changed, profit margins have been squeezed and the profit motive has become the dominant issue in the wider strategy of the business. In the last two decades of the 20th century the mining business in South Africa became part of the global mining industry, and the need for national standards to be aligned with the international business imperative, i.e. to remain competitive, became increasingly important. This change requires significant adjustment of the role of the mine surveyor—essentially, to grow from a compliance mindset to support the key business drivers of the company, which includes but is not dominated by mine health and safety. To achieve this, some intervention is required in defining the role of the mine surveyor for the 21st century. For success in this regard, it is important to establish what exactly mine surveyors do today, how they do it and to establish leading practices on all those duties. Once that is done, the intervention can be designed taking current leading practices into account, seeking best practice in the international context and aligning these with the broader business strategy.

The next section gives the results of a survey done at a leading coal mining group before any intervention. The purpose was to establish what coal mine surveyors actually did today and how they needed to align their survey duties to support the business drivers of the company.

The role of the coal mine surveyor today

Six large coal mining operations[17] were visited to record the role of the mine surveyor. The purpose was to establish what coal mine surveyors actually did, why they did it, how they did it, how they reported results and to whom the report was directed. This section summarizes this process which included comprehensive questionnaires and on-site interviews with coal mine surveyors appointed as competent persons in terms of the MHSA. The information on actual duties, how these were carried out and reporting methods were grouped to establish the scope for standardization on leading practices to support the business imperatives. This discussion is limited to the role of the mine surveyor as derived from this process. The outcome of the study was that the role of the coal mine surveyor comprised surveying; data processing; mapping; reporting; health, safety, environment and community responsibilities; and office administration functions. Each of these will be discussed separately in this section. Although health and safety issues were grouped as a separate function, their importance is such that they overlap with all other functions. A possible explanation for such overlap is that risk management on heath and safety matters is such an important driver of how business is conducted on South African mines and, as such, influences all survey functions.

Survey measurement function

Surveying involves physical measurement of features at a mine, which is governed by the mine's standard operating procedures and work instructions. Surveying measurements are done for various reasons and these may be grouped under functions required by the MHSA, positional surveys, design surveys, volume surveys and other surveys. The duties for each group are as follows:

- Duties directly linked to the MHSA are measurements required for accident scenes; monitoring surveys for slurry concentrations, slope stability, subsidence and pillar over/undermining; high risk and hazard plans; boundary verification; mine plan updates; and establishing the surface topography at a mine
- Duties concerned with positional surveys, which include network surveys, the location of exploration boreholes and surveying of refuge bays
- Duties encompassing design surveys, such as the setting out of infrastructure, mining plan features, drill plans, measurements for rehabilitation plans, geology boreholes and lines for magnetic surveys
- Measurements required for volume calculations. These are routine measurements of mining overburden, coaling, interburden, blasting throws, water concentrations, slurry volumes and stockpiles and
- Finally, other survey measurements, such as measurements for establishing water dam levels, slurry pits and the relocation of grave sites.

Data processing function

All physical survey measurements that are taken or observed in the workplace need to be processed in one way or another. Most of the measurements described above require error propagation and calculation of accurate coordinates and heights in relation to the mine survey datum. Health and safety survey measurements, such as monitoring pillar over or undermining, require additional calculations like safety factors, extraction factors and width-to-height ratios. Co-ordinates and elevations are also the base data for further processing of areas and volumes. Volumes are used as such for payment of contractor purposes but often require yet further processing for reconciliation of stockpiles and life of mine volumes, calculation of stripping ratios, swell factors and mass calculation. Most processing duties are computerized, which require different software programmes and systems integration (e.g. on-board software of survey equipment and those in the survey office) during the processing stage. The effective use and integration of such software require ongoing training and education of surveyors at the mine.

[17]An investigation into the role of the mine surveyor at mines producing other commodities will prove to be different from those identified in this section. Even though this may be the case, the principles towards investigating the role of the surveyor in these mining industries will be valid.

Survey mapping function

Processed survey data are often indicated as co-ordinates on a specific datum that describe features on maps and plans. Yet others are incorporated as statistics on production, safety and monitoring charts. As is the case with data processing, mapping is normally done electronically using highly specialized mapping software. These result in general mapping issues and decisions need to be taken on the creation of electronic layers in the software, naming conventions, availability and medium of working plans, integration of various sources of information and co-ordinate databases, survey datum and projection systems, colours and sign conventions, plan scales and frequency of updates. The mapping duties are as follows:

- The updating of statutory maps, plans and sections as required by the MHSA
- The preparation of tenure and other legal plans, which include regional plans, locality plans, mining rights plans, plotting land survey diagram (farm information) on mine plans, surface right plans indicating agricultural lease status, rezoning and servitudes, and finally, plans and information required for the relocation of graves
- To prepare and maintain working plans, which consist of mining layouts and forecast plans and
- Other mapping duties such as the preparation of electrical and water reticulation plans, rehabilitation design plans, mine rescue and ventilation plans, stone dust plans, floor contour plans, infrastructure plans, check survey plans, and digital terrain models.

Survey reporting function

Considering the vast amount of raw survey data, processed data and maps that are generated by surveyors, care must be taken on what information needs reporting, the process and format in which information is reported, as well as to whom it is reported. In order to formalize and optimize such reporting, the flow of survey information, on-mine access to it and its integrity must be controlled in order to prevent unauthorized access and over-writing of it. Reporting duties include:

- Reports to demonstrate compliance with the MHSA, which Act requires the mine surveyor to report on risks[18] pertaining to monitoring surveys, boundary encroachment, holing procedures and general production or panel layouts (called section management booklets in the coal industry)
- Reporting for resource management, which is a report on the loss of coal reserves as a result of combining legal restrictions on mining with the mine design parameters
- The month-end report, also called the Survey Certificate. The purpose of this certificate is to pay contractors for work done, compare actual results with design parameters and finally, to perform mass reconciliations. The information reported in the certificate varies but generally includes distances, areas and volumes, as appropriate, tons, stripping ratios, swell factors, safety factors, width-to-height ratios, rehabilitation results, stock reconciliations, inventories and measurement of throw results
- Other reporting duties required for material tracking, government statistical returns[19], borehole survey results, rehabilitation plans and tenure reporting, which include agricultural lease status and special requests and
- Finally, additional reports and recordkeeping are required when the mine has ISO 9000 accreditation.

Mine health and safety, environment and community function

The MHSA requires mine owners to introduce systems to ensure safe working conditions. To equip surveyors for competence in these areas, the survey office must develop risk management strategies, develop key performance areas, establish health and safety targets for the survey office and ensure proper and appropriate training for mine survey staff. The duties that resort under this function include:

- The keeping of hazard plans and records on special areas. Examples are section management booklets, monitoring records and survey risk management records
- The MHSA requirement that mine owners must prepare and implement a code of practice (COP) on any matter affecting the health and safety of employees and other persons whenever the Chief Inspector of Mines (CIM) requires such COP. In this regard, mine surveyors are involved with monitoring systems designed for combating rockfalls. Another COP that requires survey input is the ingress of water into mine workings. It is standard practice to have a stand-alone survey COP that guides all survey duties on a particular mine
- MHSA requirements to ensure that no persons are endangered by risks such as being struck by rock or other material associated with subsidence, collapse of surface buildings and structures resulting from the removal of support, and risks related to mining in the proximity of other underground workings
- The MHSA requirement that the employer must ensure that the surveyor appointed as competent person must be aware of all working mining faces, surface structures affected by mining, workings being abandoned and safety pillars that are being, or have been, removed. Once aware of these events, it is the mine surveyor's responsibility to put effective compliance systems in place and report hazards, risks and non-compliance to management
- The MHSA requirement for the mine owner to respect the mine boundary lines and pillars. The mine surveyor must indicate boundary pillars on the mine plan, follow instructions from the mine manager and communicate events on both sides of the boundary line. When

[18]The MHSA requires all employees to report any situation presenting a health and safety risk.

[19]Required by the Department of Minerals and Energy in terms of the MHSA and MPRDA.

working faces approach the boundary pillar, the surveyor must give adequate warning and continuously monitor the situation and
- Survey input to the rehabilitation plan and community issues, such as investigating complaints[20] registered at the mine and the relocation of grave sites.

Survey office administration function

Finally, the surveyor appointed as the competent person is an administrator. Appropriately, the first office administration duty deals with all record-keeping required in terms of the MHSA. Since many of these records will be in electronic format, consideration must be given to back-up medium, intervals and naming conventions. Leading practice requires all documents, procedures and practices of the office to be recorded, properly labelled and filed in a way that these are traceable and easily retrievable.

The second duty is human resource management, which includes appointment of the appropriate number of staff who must be equipped with proper skills, further training and education. This duty includes developing job descriptions for all staff and career development planning.

A third duty is to acquire and maintain survey equipment and software. With the rapid advances of technology in the mine survey field, it is important for mine surveyors to stay abreast and recognize business improvement opportunities that will either increase revenue for the mine or improve productivity as a result of implementing such new technologies.

Conclusion

This article has expressed the view that the role of the mine surveyor has not changed significantly from the Middle Ages to 1977. By comparing the current role with that described by Dennis, it seems that although some duties were added over time, the main survey functions did not change much. In the meantime, the industry has undergone significant changes and these developments pose new challenges to the mine survey profession and the role of the mine surveyor in a profitable, healthy and safe mining industry. In future, the role of mine surveyors in the national context will continue to be shaped by legal compliance regarding mine health and safety (in terms of the MHSA), preparation of maps, plans and diagrams (in terms of the MPRDA) and professional registration (in terms of the PLATO Act). However, the specific role of the coal mining surveyor into the 21st century will probably change from mainly satisfying legal requirements to survey functions that strongly support the imperative business drivers of the company.

Regarding qualifications and competence of coal mine surveyors, curricula of qualifications will have to include specialist modules on the roles, functions and duties identified in this paper, as well as greater emphasis on business processes and mineral resource management principles. New developments in technology will continue to affect efficiencies and the number of surveyors required per operation. They also have to familiarize themselves with the processing of high density and continuous streams of data for reporting in a way that increases the value of the business.

In conclusion, the search for best practice starts with analysing current practice and understanding the business drivers of the company. The maturity journey for achieving this goal is firstly, to formulate the strategy by designing a process to achieve the goal; secondly, such process needs implementation and management of adjustments to current practices; and thirdly, a champion to focus on the outcome and commit resources to support the process. Consideration of the following elements of the maturity journey will be critical:

- The need for surveyors to measure, process and report material in a manner consistent with the business drivers of the company. There is an increasing need to report material or product along the mining value chain in relation to specific mining processes (activity-based) and equipment (major fleet of equipment)[21] associated with that mining activity
- With regard to the reconciliation of material along the mining value chain, we see a shift to measurement and reporting of all measurement results, such as belt scales, truck loads, plant scada systems, etc. Reconciliation cannot truly be successful if there are too many measurers along the value chain. A single party must take responsibility for reconciliation of material. Such reconciliation must take account of the different confidence limits of measurements along the value chain for accurate reporting over the entire mining process; and
- The role of the surveyor in mineral accounting and quality assurance to meet mine requirements, market specifications, corporate governance standards and reporting across operations in a global context.

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[20]For example, the survey of ground movement in the form of cracks, subsidence and sinkholes by establishing distance from mine, correlation with underground workings and scale of the problem.
[21]Fixed equipment, e.g. beneficiation plants; and mobile equipment, e.g. dragline, truck-and-shovel.
Supervisory control and data acquisition.