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Development of the MOSH Leading Practice Adoption System – a science-based system for managing behaviour change

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Synopsis

Poor occupational health and safety performance in the mining sector during the 1980s led to establishment of the Leon Commission of Inquiry and ultimately to the Mine Health and Safety Act of 1996. In striving to achieve the tripartite OHS milestones established in 2003, the major mining companies agreed to pilot a system focused on facilitating the identification and widespread adoption of leading practice. The system included the use of behavioural communication techniques to address resistance-to-change effects. Piloting of the system served, however, to initiate a lengthy process of learning and system development, as many of the fundamental concepts and techniques of behavioural communication were found to be inadequately understood.

Achieving a practically useful understanding of these key concepts and processes took as long as three years, from 2008 to 2011. Evolution of this understanding is outlined in detail and key aspects of the resulting system and its processes are presented in summary form. The emergence of resistance at some mines to use of the MOSH adoption process is recognized and a constructive approach to addressing this issue is outlined.

The substantial improvement in safety performance achieved by industry since 2003 is described and various contributing factors are identified, with the adoption system being one of these. In addition to facilitating the adoption of various leading practices, particularly in the area of falls of ground, an important contribution of the adoption system is considered to be the focus on OHS issues that it has engendered in a large number of key people across the industry. The need for a much greater focus on occupational health issues in future years is highlighted and the new OHS milestones agreed to in 2014 are presented. In conclusion, the value of adopting a holistic long-term systems approach to address multi-facetted challenges, such as behavioural change and occupational health and safety, is highlighted.

Keywords

occupational health and safety, leading practice, technology transfer, innovation, decision science, behaviour change, mental models, risk communication, leadership behaviour, resistance to change.

Introduction

Development of the Mine Occupational Safety and Health (MOSH) Leading Practice Adoption System was initiated by the Chamber of Mines of South Africa on behalf of its members in April 2007. Its development formed part of a concerted effort by South Africa's major mining companies to achieve the 2013 Occupational Health and Safety (OHS) milestones that were agreed to by the tripartite partners in 2003 (MHSC, 2003). In many respects, the establishment of these milestones marked a turning point in addressing the long-standing OHS challenges in the mining industry.

It is in the context of this progress that development of the MOSH Leading Practice Adoption System is relevant. Although features of the Adoption System have been described in a few publications (van Zyl, 2010; Malatji and Stewart, 2013; Stewart and Butte, 2017, Hermanus, Coulson, and Pillay, 2014), no published paper has outlined its lengthy development process or clarified its science base. A similar comment applies to the many unpublished conference presentations, which have focused on the adoption of particular practices at mines. Much about the system and its development is thus not known or correctly understood.

Accordingly, this paper sets out a comprehensive account of the development process, including:

- Historical background to the development of the system
- Exploratory investigations prior to initial development of the system
- An outline of the originally envisaged system
- The extensive development that occurred after piloting of the originally envisaged system
- A summary of the developed system and its science base
- An assessment of the multifacetted impact of the system to date.

Background

Long-standing nature of the OHS challenge

The severity of the mining industry's long-standing OHS challenge is illustrated in Figure 1.

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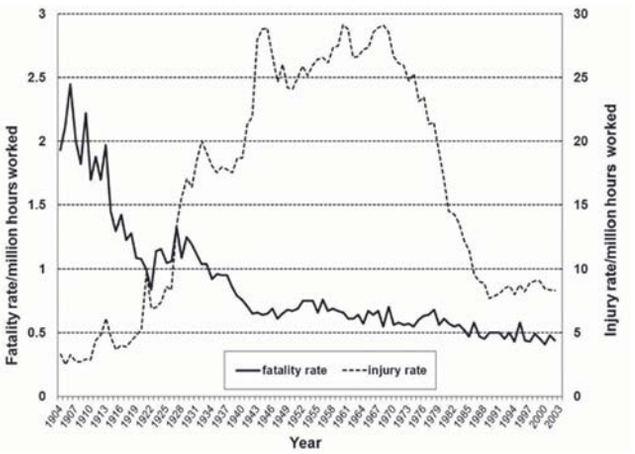

Figure 1—Fatality and injury rates in South African gold mines 1904–2002 (Gouws, 2004)

It should be noted that a fatality rate of 0.5 per million hours worked equates to an annual fatality rate of 1.3 deaths per thousand workers, and that in 1988 the gold mining industry employed as many as 480 000 workers (Harrington, McGlashan, and Chelkowska, 2004). Figure 1 shows that despite an initial period of rapid improvement, high fatality rates in South African Gold mines persisted through to 2002. The changing nature of the safety challenge over the years contributed to this. In the early years, as the extent and depth of mining increased, death from heatstroke due to extremely hot working conditions became a major problem. By 1930 the number of deaths per year from heatstroke had reached a level of about 1 per thousand (Wyndham, 1974). Significantly, as described elsewhere (Stewart 1982), this problem was largely eliminated through the development and application of effective heat tolerance testing and acclimatisation procedures. However, continual change in the scope and nature of mining inevitably gave rise to new challenges. This is illustrated by Figure 2, which, for the period 1984–001 shows the number of accidents per year across the industry that resulted in four or more deaths. Some of these major accidents were disasters, such as explosions and fires, which involved many more than four deaths, but many were caused by falls of ground. In the 1970s and 1980s, much attention was thus focused on the rock pressure problem and the elimination of rockbursts and fall-of-ground accidents. Notwithstanding these efforts, the rate of reduction in the industry's high fatality rate remained disappointingly low (Stewart, 1995).

Emerging dynamics to address safety and health at mines

Towards the end of the 1980s, the high fatality rate and its marginal rate of improvement, together with deteriorating financial circumstances and labour unrest, gave rise to a number of important dynamics in the mining industry. Significantly, given the looming cutbacks in the industry's cooperatively funded research programme, and in order to ensure continued focus on health and safety research, the then Government Mining Engineer established a levy-funded programme of research into occupational health and safety (Stewart, 2004). This programme later became the responsibility of the tripartite Safety in Mines Research Advisory Committee (SIMRAC), established under the Mine Health and Safety Act of 1996. However, and much more importantly, the emerging dynamics led to growing calls for the establishment of a Commission of Inquiry into occupational health and safety at mines.

The Leon Commission of Inquiry into Safety and Health in the South African Mining Industry was established in 1994 and its work was undertaken in the same year. Almost in parallel, and with much input from South African delegates, the International Labour Organization developed its Convention 176 on Mine Safety and Health. The convention was finalized in 1995. Both of these processes had the important effect of involving and focusing the attention of top-level management in each of the South African tripartite partners on how best to address the challenge of health and safety in mines. Significantly, the recommendations of the Leon Commission, together with the provisions of the ILO Convention, served to guide development of the Mine Health and Safety Act of 1996, and thus the tripartite structures and regulatory systems for addressing health and safety in South African mines that were established under the Act.

Establishment of tripartite-agreed OHS milestones

It is against this background that the Occupational Health and Safety milestones agreed to in 2003 by the tripartite partners of the Mine Health and Safety Council must be seen. In particular, it brings out the fact that the 2013 milestones agreed to in 2003 represent the articulation of a growing consensus across industry to both establish, and collectively address, the ultimate goal of achieving conditions of *zero harm* to persons at work. Progress in this direction was significantly accelerated in 2005 when the CEOs of major mining companies publicly committed their companies to achieving both the milestones and the ultimate goal of zero harm. This commitment led to the mobilization of needed resources. In particular, it led to establishment of a high-level task force charged with identifying how best to improve health and safety at mines. One of the areas identified for investigation was that of achieving successful technology transfer, and it was the work commissioned through the

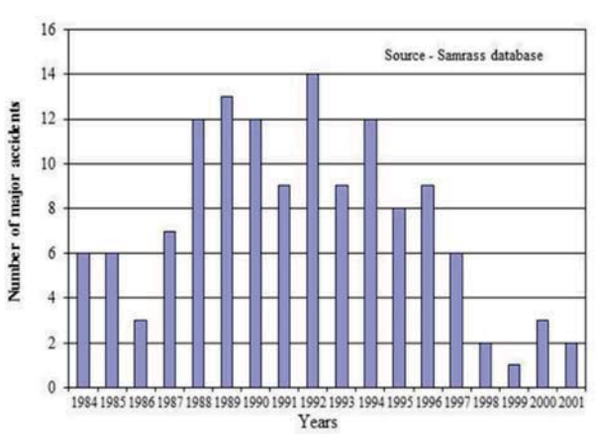

Figure 2—Number of major accidents per year, 1984–2001

Chamber of Mines to investigate this issue that ultimately evolved into the development of the MOSH Leading Practice Adoption System.

Exploratory investigations

The high-level task force recognized that a fresh approach would be needed to achieve the OHS improvements required by the 2013 milestones. In particular, it recognized that the limited time-scale for the required improvements made the adoption of a systematic R&D approach unrealistic. Accelerated use of available technology and best practice was thus identified as an important means of bringing about the improvements sought by 2013, and this became the focus of the work commissioned by the Chamber in 2007 on behalf of the task force. Accordingly, the first step in undertaking this work involved exploratory investigations to review both past and emerging industry experience with the adoption of new technology or practice.

At the time of commissioning the work it was also recognized that a fundamental understanding of the barriers and aids to both sharing and adopting new technology and practice should be established. The importance of achieving such an understanding had emerged in the approach taken by the Mining Association of Canada in their initiative on sustainable mining, (MAC, 2003). A parallel collaborative investigation by Decision Partners, specialists in decision-making and behaviour, was thus also commissioned by the Chamber to acquire this understanding (Stewart, 2007a, 2014).

Available industry experience

During the 1980s, effective technology transfer had become an increasingly important consideration within the Chamber of Mines Research Organization (COMRO), and various workshops and review studies were thus conducted during the period 1980–93. The findings of these investigations, which were summarized in various internal documents, were thus reviewed to distil the key concepts and insights of relevance to the challenge being addressed. In addition, the multifaceted work undertaken by the National Advisory Council on Innovation on the utilization of research findings (NACI, 2003) was similarly reviewed.

Given the ongoing accumulation of experience in operating companies in both technology transfer and the adoption of new practice, the latest experience of a wide range of organizations was also investigated. This included not only the major mining companies committed to achieving the 2013 OHS milestones, but also others. These investigations led to the development of a number of noteworthy insights. The various organizations investigated and the mechanisms identified are presented in Table I, and examples of the many key concepts and insights derived from the review process are given in Table II (Stewart, 2007b).

The findings and insights from this work provided a sound basis for selecting the mechanisms and processes included in the system that was developed and submitted in 2007 to the Chamber for consideration (Stewart, 2007a, 2014).

During the course of the investigations, the instructive value of considering these mechanisms and processes within the broad concept of innovation emerged. Importantly, the concept deals with the full spectrum of innovative activity, from creation to successful application. The requirement for successful application was particularly noteworthy, as it is an essential requirement in meeting the 2013 milestones. The scope of the concept is illustrated by the following definition:

> **Innovation** *involves the creation, exchange, evolution and application of knowledge, in whatever form, for the*

Table I

Organizations investigated and identified technology transfer mechanisms

Organizations investigated		
Impala Platinum	Sandvik	University of the Witwatersrand – School of Mining and Centre for Sustainability in Mining and Industry
Eskom	Sasol Chemicals	Chamber of Mines – Coaltech 2020
World Association of Nuclear Operators	Sasol Mining	International Council on Mining and Metals
Anglo American plc	Anglo American Platinum	Engen
Reunert Systems	BHP Billiton	Gold Fields
Australian Minerals Industry Safety and Health Centre	SIMRAC	Western Mining
Mechanisms identified		
Standalone organization	Communities of practice	Charter-based holistic health and safety management system
Benchmarking database	Project-based steering committees	A central facility for demonstration projects
Steering committees involving key stakeholders	Global peer group review mechanism	Electronic information systems
Specialist focus groups	Local peer group review mechanism	Incident-driven identification of technology and best practice
Mandatory company standards	Partnerships with suppliers	Centrally coordinated technology management system
Manager-level presentations and visits to share best practice	Focused high-level task force	Round-table forum to facilitate development of improved equipment

Table II

Concepts and insights derived from past work on technology transfer

No.	Examples of identified concepts/insights
1	Technology transfer comprises two distinct phases. The first phase involves providing sufficient understanding of the technology and its performance to enable potential recipients to decide whether to adopt the new technology/practice. The second phase is transfer of the knowledge and skills necessary to implement the technology.
2	The potential recipient of a technology/leading practice needs to have a real business incentive to embark upon the acquisition and adoption of the new technology/leading practice.
3	Recipients of the new technology need to be assisted, and to have access to expert assistance at an early stage of the transfer process.
4	The recipient organization needs to have a person at an appropriate level to facilitate and champion the technology transfer process.
5	The technology champion needs to be adequately supported by both his/her superiors and the technical experts of the technology/leading practice.
6	Champions need to be innovative and have credibility and integrity, placing successful implementation above personal ambition.
7	When the risk of implementing a new technology or practice is too great for the first adopter to bear alone, some form of underwriting or risk sharing may be necessary to facilitate successful transfer and implementation.
8	People at all levels must see the benefits to themselves of adopting the technology/practice.
9	Peer communication of applications and benefits of new technology/practice should be facilitated as it enables and generally assists the process of transfer and adoption.
10	The first recipient organizations to adopt a new technology/leading practice should be those that have the greatest need for and potential to benefit from successful adoption.

success of an organisation, the vitality of a nation's economy, and the advancement of society as a whole. Innovation cannot be claimed in the absence of successful application.

Expert model of innovation

While the NACI study referred to earlier had brought out the instructive value of an expert model of innovation, the more detailed expert model of innovation available from Decision Partners (Butte, 2007) was found to be even more useful. Accordingly, this model was then used to guide the overall system design aspects of the present work. A schematic of the model is presented in Figure 3.

A particularly important point brought out by this model is that the innovation process *starts with the establishment of a management orientation that supports and enables the innovation process*. This is a very important first step. In this context, it is important to point out that the various dynamics and developments described earlier had, unknowingly, already indirectly contributed towards the establishment of such a management orientation over the period 1990 to 2005.

Mental models research

In the collaborative work undertaken by Decision Partners, a programme of mental models research was conducted to identify barriers and aids in the South African mining industry to both sharing and operationally adopting new technology and practice. Their approach was based on extensive research, summarized by Morgan *et al.* (2002), that showed that peoples' judgement about complex issues is guided by their mental models, which are *the tacit webs of belief that they draw on to interpret and make inferences about issues that come to their attention*. Accordingly, a mental model may be defined as follows:

*A **mental model** is the sum total of all experience, in the form of knowledge and beliefs, which may be correct, in error, or incomplete, that a person has acquired about a particular topic or situation. It is the basis upon which individuals decide and respond to issues that arise.*

It follows from this that incomplete or incorrect beliefs and information can lead to compromised judgements and inappropriate behaviour.

Mental models cannot be determined without empirical research. The mental models research process undertaken by Decision Partners was briefly as follows. The important first step involved developing an expert understanding of the key factors and dynamics at play in the process of sharing and operationally adopting new technology and practice. This was derived from a meta-analysis of OHS conference presentations, and also discussions with selected industry experts, and was expressed in the form of an expert model. The methodology for deriving such expert models is considered in more detail later. The derived expert model was then taken as an accurate statement of all factors that materially influence OHS performance, including the process of sharing and operationally adopting new technology or

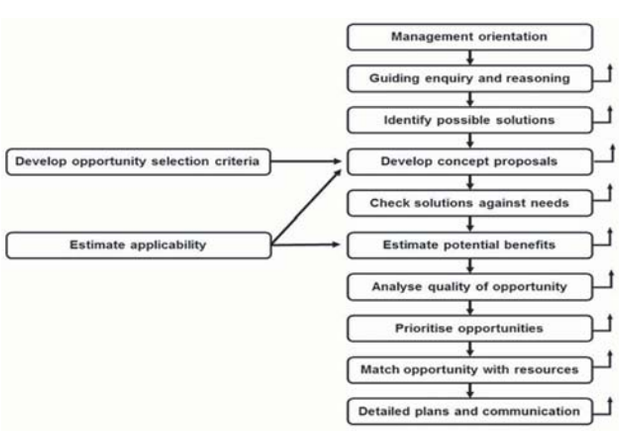

Figure 3—Schematic representation of expert model of innovation (Butte, 2007)

practice. One-on-one semi-structured interviews were then designed and conducted with a selection of individuals and their responses analysed to determine their beliefs and views in various areas. Together, these beliefs and views represent their prevailing mental models. Key findings from the study are presented in Table III. The summary report prepared by Decision Partners on their methodology and findings was included in the report setting out the adoption system that was proposed (Stewart, 2007a, 2014). An important aspect of this table is that in addition to identifying key barriers that need to be addressed, it identifies many avenues that can be positively built upon in adopting any new technology or practice.

Key success factors

In developing the proposal presented to the Chamber in 2007 (Stewart, 2007a, 2014), the following key success factors were identified and taken into account.

1. The key elements of the proposed system must be simple and clear so that industry executives are readily able to consider and adopt them as a basis for enabling implementation of the system.
2. The adoption mechanisms, and also the system, must engender a sense of Industry ownership, particularly for any aspects that might be centrally sponsored or located.
3. The adoption mechanisms must be able to accommodate the different approaches that may be required for the adoption of different technology and\or best practice.
4. The system must facilitate focused attention on the few top-level priorities identified by industry.
5. The time spent by industry persons in working with the system must be minimized and free of undue complexity.

Originally proposed system

Against the above background, the proposed system was designed (Stewart, 2007a, 2014) to facilitate the identification, sharing, and widespread *adoption of*:

- Worthwhile *best practice*
- Worthwhile *technology*, such as that emerging out of the SIMRAC research programme
- A *combination of practices and technologies* specially identified to address a *priority area* of occupational health and safety concern.

In developing the system it was recognized that no single mechanism could be used to achieve widespread operational adoption of technologies or practices in all situations. This important finding emerged during the review investigations. Although various mechanisms and processes individually delivered good results in particular circumstances, no single mechanism was successful in all circumstances. This explained the diversity of reported views and advice on how to achieve the adoption of technology or best practice. Accordingly, a system that used different mechanisms and processes to achieve both the identification and adoption of needed technology or practice for each of the above three situations was developed. However, the essential logic for the three situations remained constant and relatively simple, as follows:

- Assess risks and identify potential risk reduction solutions (operational improvements)
- Identify and document the most promising risk-reduction solution (technology or practice)
- Develop a plan for securing widespread adoption of the selected option

Table III

Key findings from mental models research into prevailing OHS factors across industry (%: Percentage of interviewees who identified the indicated factor)

Aids to implementation (adoption)	%	Barriers to adoption	%
Communicating with management and workforce	70	Resistance to change	55
Demonstrating personal commitment	68	Cost	55
Actively supporting implementation	52	Workforce not seeing benefit	43
Ensuring appropriate technology	29	Technological challenges	33
Providing training	29	Lack of management buy-in	28
Engaging workforce / management for buy-in	27	Training capacity	23
Reinforcing OHS culture	13	Production pressures	20
Monitoring results	13	Lack of workforce buy-in	20
		Lack of skills and education	20
		Organizational culture	19
		Social barriers	17
		Lack of time	15
		Inappropriate incentives	13
		Generation gap	12
		Other	21
Leading OHS activities at mines	**%**	**Most effective communications**	**%**
Implementing technology and best practice	47	Personal interaction	92
Conducting technology R&D	43	Meetings and workshops	55
Monitoring OHS performance	40	Underground site visits	27
Managing operations for OHS	34	Presentations	18
Coaching, training, and communications	25	Campaigns	8
Reinforcing safety culture	17	Visual communications	8
Accident assessment and response	8	On-the-job training	8
Seeking technology or best practice	4	Combination of methods	37
		Other	19

- Demonstrate and document the adoption process and the effectiveness of the selected option
- Communicate adoption details and potential benefits to industry (potential adopters)
- Facilitate a process to achieve widespread adoption.

Key features of the proposed system

In line with the above, the key features of the originally proposed system, which are considered essential, are shown schematically in Figure 4 and explained briefly below.

- *Enabling leadership and management*—In keeping with the expert model presented in Figure 3, the proposal outlined the need for leadership and management to create an environment that is enabling and reinforcing of adoption activity, and personally rewarding to those engaged in the adoption process. In particular, it included the establishment of recognition and reward arrangements for individuals who significantly facilitate the adoption process.
- *Direct industry involvement*—The importance of industry ownership and buy-in emerged as one of the most strongly and consistently expressed views in the exploratory work. Accordingly, the proposal required that the adoption teams, which lead and facilitate the adoption process, should be staffed by persons seconded from industry. Appropriate use of industry experts was also established as a core operational principle of the Adoption System.
- *Specialist secretariat support*—A key finding of the exploratory work was the difficulty that industry persons experience in devoting time to projects that are additional to their normal operational responsibilities. Accordingly, the system included a specialist secretariat to both enable and support the adoption teams, and also to ensure operational continuity and effective institutional memory.
- *Peer group reviews*—Conducting peer group reviews was identified in the exploratory investigations as an effective mechanism to identify and spread the adoption of good practice. The proposed system thus included the use of peer review teams to conduct detailed reviews of operations at participating mines to identify existing best practice, as well as areas in need of improvement. These reviews would be done at the request of mines, or at the request of industry but with approval by the mine in question. Best practices identified during the review would be documented, and then, with the permission of the source mine, openly communicated to other participating mines. The experience of the review team, along with best practice identified in previous reviews, would be considered in advising on any weaknesses identified at the mine being reviewed. Findings from the review would be presented to the mine in a confidential report. As explained later, this aspect of the originally proposed system was held back for later consideration.
- *Demonstration projects*—This element involved demonstrating adoption of an identified leading practice at an operating mine. Such projects would enable the leading practice or technology in question, as well as the adoption process, to be confirmed and refined, to the benefit of future adoption mines. Importantly, through site visits and informal peer-to-peer interaction, key information would be communicated to potential future adopters. In this way, the demonstration process would help spread and build the credibility of both the leading practice and the adoption process.
- *Communities of practice*—For each leading practice, this involved establishing a group of persons directly concerned with, or interested in adopting, the practice to voluntarily interact and exchange useful information in a relatively informal way. This is in line with the literature on communities of practice (Wenger, 1998; Smith, 2006; The Distance Consulting Company, 2000). Such groups serve not only to assist the widespread adoption of the practice, but also in its improvement. However, as outlined later, a much more structured approach was preferred.
- *Champions*—The positive role of 'technology champions' in facilitating the adoption of new technology was a key finding in the review investigation. Accordingly, it was established as a role that the head of each adoption team is expected to play. The key attributes of such a champion were then identified as major considerations in the selection of persons to not only lead the adoption teams, but also to energize and spearhead the process of achieving widespread adoption of the technology or best practice.
- *Facilitating structures and processes*—The establishment of simple but effective facilitating structures and processes was clearly fundamental to success of the system. Noting that different processes apply to each of the three adoption situations presented earlier, the essence of the structure that was originally proposed is presented in Figure 5, but without the Tripartite Advisory Body, which came later.
- *Quality communication*—All parties who play a role in the adoption process are communicating in one way or another all the time. Indeed, it was recognized that even the absence of action, and/or the presence of silence, is in practice a real form of communication; usually negative, and sometimes very powerfully so. This was a very important realization. Accordingly, the

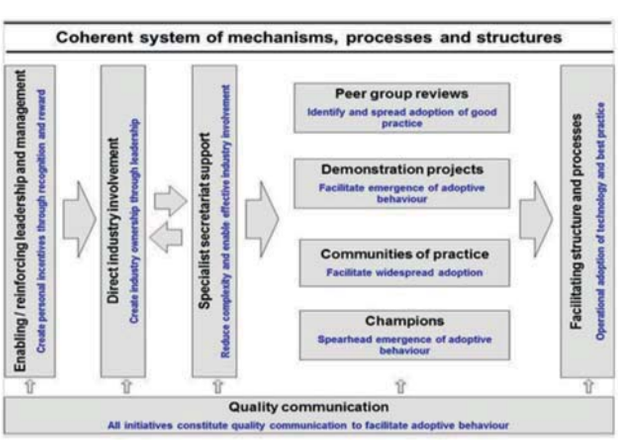

Figure 4—Key elements of originally proposed system for adoption of new technology and practice

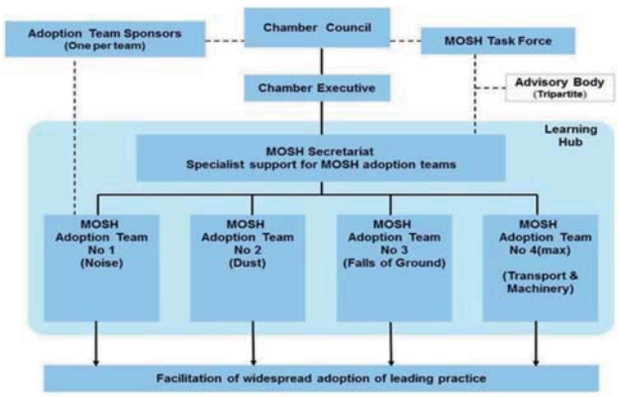

Figure 5—Structural arrangement of the proposed Adoption System

proposed system recognized that successful adoption depends on the full range of communications coming from persons having a stake in the adoption process. In effect, the right thing needed to be communicated to the right persons at the right time and in the right way. Quality communication was thus identified as fundamental to the collective effectiveness of all elements of the proposed Adoption System.

Decision to pilot the system

At the time of presenting the proposed system to CEOs of the major mining companies, it was recognized that pockets of excellence existed across the industry and that some mines were already achieving OHS performance levels in line with that required by the 2013 OHS milestones. This led industry to decide that initial application of the proposed system should be confined to identifying existing pockets of OHS excellence, and then facilitating the widespread adoption of such practices by other mines across industry. Significantly, it was agreed at the highest level that intellectual property in the area of OHS should be freely shared across industry. This is an important aspect of the environment created by leadership to enable innovation. Towards the end of 2007 it was agreed that the proposed system should be piloted, starting in 2008, but with its scope confined to *facilitating the identification and widespread adoption of existing leading practice*. Although the peer review process described above was thus excluded for later consideration, a form of peer review was used to identify existing leading practice, defined as follows:

> A *Leading Practice is a practice that is particularly effective at eliminating or reducing a particular occupational health and safety risk situation, and has potential for beneficial application in similar situations at other mines. It is selected by a MOSH Adoption Team following a rigorous selection procedure.*

Piloting of the system

Piloting of the down-scoped system, which became known as the MOSH Leading Practice Adoption System, formally commenced with a planning workshop in March 2008. A number of important enabling steps were, however, taken before this workshop. Firstly, towards the end of 2007 the MOSH task force identified that *falls of ground, silica dust, noise, and leadership* should be the four areas of OHS risk on which attention should be focused. Secondly, and in line with this, arrangements were made for suitable persons from industry to be seconded to the Chamber to serve as Adoption Team Managers in these areas. They were thus available and able to assist in preparing for the workshop, by providing input into the workbook that was collaboratively developed to guide activities during the workshop (Decision Partners 2008). Lastly, the process of identifying and appointing the high-level Adoption Team Sponsors depicted in Figure 5 was initiated. Appointment of these persons took time, but the important linking and guidance role played by these sponsors has proved to be an important aspect of the Adoption System.

Planning workshop

Participants in the planning workshop included the Adoption Team Managers as well as discipline specialists from the major mining companies. The specialists were selected on the understanding that they would later become advisory members of the adoption teams, but with execution of the agreed programme of work being undertaken by the full-time members of the team. At the planning workshop, the essence of the adoption system and process being piloted was presented as follows:

MOSH Task Force takes overall responsibility for enabling achievement of the 2013 OHS milestones

↓

Task Force identifies up to five top-level industry priorities to be addressed in parallel

↓

Industry leadership provides the necessary resources, in line with their decision to pilot the system

↓

Task Force facilitates establishment of adoption teams to plan and undertake the necessary work

↓

Adoption teams identify best opportunities (leading practices) for OHS improvement

↓

Adoption teams implement action plans to achieve widespread adoption of identified practices

↓

Task Force monitors and assesses outcomes and decides future activity.

During the course of a five-day workshop, each of the four adoption teams assessed the risks in their respective areas and identified the leading practices considered to have potential to improve OHS performance in their area. They then conducted a systematic review to select the practice with the greatest potential, and developed an initial draft plan outlining their future activities. Following the workshop, the teams then set about finalizing and implementing their plans. As outlined in the points that follow, this proved to be problematical and led to a significant learning experience. In retrospect, it marked the beginning of a process that led to clarification and development of many important aspects of the Adoption System, and in particular, the behavioural aspects of the system. Significantly, it is the behavioural aspects of the system that most differentiate it from other processes of innovation.

Process uncertainty

Soon after the planning workshop, it became apparent that the adoption teams differed significantly on how to implement the adoption process. Progress was thus both variable and limited. This issue was addressed by developing and providing a generic schedule to guide adoption team activity. While this provided clarity at one level, it did not provide sufficient guidance at the detail level on a number of the scheduled activities. In particular, it emerged that there was inadequate understanding by the teams of how to develop the behavioural communication plans required to facilitate widespread voluntary adoption of their selected leading practices. With the benefit of hindsight, it is now clear that this inadequate understanding was at a fundamental level. It took as long as three years to evolve a full understanding of the behavioural communication concept, and how it formed part of the broader mental models concept explained earlier in relatively simple terms. Failure to pass on this understanding right up front was a major weakness of the workshop. Unfortunately, it continues to be a challenge in introducing the system to new users. It is now recognized that achievement of the required understanding and buy-in involves a time-based process that cannot, in effect, be reduced to an event. An explanation of this important realisation is provided later.

Guidance notes – an emerging handbook

The uncertainty and variation between the teams in their approach to addressing certain of the scheduled activities led to the preparation of guidance notes to assist the teams to identify and collectively agree on how these aspects should be addressed. The initial guidance notes dealt with issues such as:

- A generic plan to guide the scheduling of adoption activity
- Identification of potential adoption mines and the key persons at those mines
- Documenting of the selected leading practice at its source mine
- Issues to be agreed with a mine prior to it hosting a demonstration project
- Establishing a Community of Practice for Adoption (COPA).

The value of such guidance notes was soon realized, and it became clear that it would be best if all guidance material were coherently consolidated into a single expandable handbook. Accordingly, the issues to be covered in such a handbook were collectively agreed, and a systematic approach to preparing the required guidance material commenced. Over the years, as new understanding and requirements emerged, the Handbook was updated and provided to the MOSH Adoption Teams for their use. The current version of the Handbook, which serves as a resource and guidance document to members of the Chamber's Learning Hub, including the adoption teams, is at revision 4.1 (Stewart, 2014). The Handbook was not, and is not, intended for general use at mines.

It will be evident from what follows that piloting of the system effectively became a process of ongoing system development as experience and understanding evolved.

Development of MOSH behavioural processes

Development of a proper understanding of the MOSH behavioural processes within the Learning Hub was both iterative and at times confusing as new concepts were disentangled from deeply embedded past experience. This stepwise learning and understanding of the science-based mental models concepts (Morgan *et al.*, 2002), which is described below, emerged in collaboration with Decision Partners. It emerged over the period 2008–2011, approximately in the following order:

Step 1: Recognition of the special nature of behavioural communication
Step 2: Appreciation of the need for one-on-one open-ended direct enquiries to identify the issues to be addressed through behavioural communication
Step 3: Recognition of the need for a systematic approach to analysing direct enquiry data
Step 4: Recognition of the need for the risk assessment to serve as a fully detailed expert model
Step 5: Appreciation of the logic and process in developing behavioural communication plans
Step 6: Recognition of leadership behaviour as an integral aspect of the behavioural process
Step 7: Recognition of the need to customize behavioural plans
Step 8: Recognition of the integrated systems nature of the behavioural processes.

The concept of behavioural communication

For many, it was difficult to understand why, and in what way, 'behavioural communication' was different from other forms of communication directed at achieving behavioural change. Some found it difficult to appreciate that the key difference lay in the way in which the content of the communication was derived. In particular, it needed to be derived from a careful process of enquiry in order to empirically determine the knowledge gaps, misperceptions, myths, and other aspects of the prevailing mental models that were influencing the behaviour in the intended recipients. Behavioural communication was thus the set of messages specifically designed to address these and other mental processes that influence behaviour.

It was eventually appreciated that such communication provides persons with information and understanding that enables them to make better decisions. Such communication is thus empowering. Importantly, it results in more appropriate behaviour in response to circumstances as they arise. It therefore has the power to induce a change in behaviour in an entirely respectful way.

Behavioural communication is thus in principle quite different from similar-sounding communication delivered with the purpose of telling or instructing people how they should behave in various circumstances. Unfortunately, the latter is typical of much of the communication traditionally used in the mining industry and thus deeply imbedded in many experienced mining personnel. Adoption of the new paradigm, and the various processes described below for its implementation, proved to be a challenge to such people.

Development of an expert model in assessing risk

While the need to conduct a detailed risk assessment to assist

with the identification and selection of the most beneficial leading practice resonated with the adoption teams, the need for it to also serve as an expert model of the situation was clearly not adequately emphasized during the planning workshop. It was not initially appreciated by all that the risk assessment, expressed in the form of a causal chain, was indeed a form of expert model. The required rigour of the process in developing a fully detailed expert model had thus also not been adequately outlined.

Accordingly, and in keeping with their experience, the adoption teams had focused on the need to identify the key risks and then on how best to address the risk situation. The need for a fully detailed and accurate expert model as a basis for identifying the knowledge gaps, misperceptions, myths, and other mental processes that would be needed later was thus not properly appreciated. This only emerged much later, during the process of developing behavioural communication plans, when the need for such information became clear.

In regard to an expert model, it was important to emphasize that the model must not simply become the adoption team or management's detailed view of the situation. Development of an expert model must involve a process that enlists and considers input from expert sources at all levels. Clearly, the finally agreed outcome of such a process may differ considerably from the view initially held by either the adoption team or operational management.

As a more complete understanding emerged of the crucial need for a high-quality expert model in deriving a sound behavioural communication plan, the value of also developing and expressing the expert model in the form of an influence diagram was recognized. Accordingly, detailed guidance for developing both forms of expert model were developed and made available to the adoption teams. The essential elements of these two forms of expert model are outlined below.

- *Causal chain risk assessment*—A causal chain risk assessment covers the following three primary elements in assessing and describing the risk situation, in both qualitative and quantitative terms:
  - The nature of the hazard
  - Exposure to the hazard
  - Outcomes from exposure to the hazard.

The guidance developed to assist in producing such a risk assessment pointed out that, depending on the situation, each of these elements may warrant being subdivided into sub-elements. Particular aspects of each of the elements then need to be identified and fully described, with data gaps in need of investigation also being identified, along with weaknesses in control and mitigation strategies, and also ways in which the risk can be reduced for those most at risk. The guidance included the template shown in Table IV for presenting the risk assessment.

- *Influence diagram*—An influence diagram similarly identifies the key factors involved in the risk situation, as well as their causal links, but in a way that more clearly depicts the way in which each factor influences other factors. As shown in Figure 6, each factor serves as a node in the influence diagram, with various shapes being used to depict different types of node. The influences are then represented by arrows connecting each node to other nodes that the factor influences. Descriptions of the various factors and each of the influences are then recorded to complete the expert model.

Direct enquiries to identify prevailing mental models

Although the adoption teams readily accepted that the prevailing mental models of a group of persons needed to be determined empirically, the procedure for doing this was initially unclear. Once again the high-level conceptual guidance provided during the initial planning workshop needed to be operationalized into a set of practical guidelines and procedures for planning and conducting a programme of direct enquiries.

Guidance was thus developed for the preparation of a protocol, including a questionnaire, for use in confidential interviews with an appropriate selection of persons. The selected persons needed to be drawn from the complete set of potential adoption mines, and to be representative of persons who would be directly involved in adoption of the leading

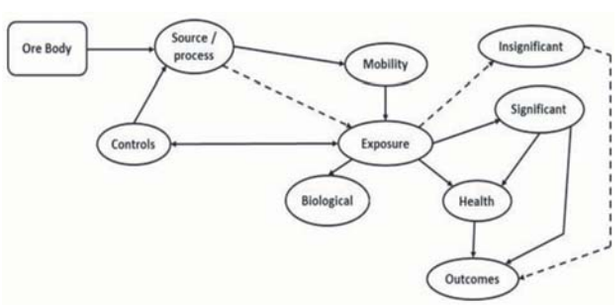

Figure 6—Expert model for dust risk in an early stage of development

Table IV

Tabular format and content requirements of a causal chain risk assessment

Part A: Causal Chain		
Nature of the hazard	Exposure to the hazard	Outcomes of exposure
Data gaps	Data gaps	Data gaps
Part B: Current risk controls and strategies		
Risk controls / strategies	Risk controls / strategies	Risk controls / strategies
Weaknesses	Weaknesses	Weaknesses
Part C: Possible improvements in risk mitigation controls and strategies		
Improvements	Improvements	Improvements
Possible new practices	Possible new practices	Possible new practices

practice. This qualitative research process required that about 25 to 30 people be selected and interviewed. Although larger numbers could be used, previous experience had shown that little additional information emerged after analysis of about 25 to 30 interview records.

The questionnaire needed to be comprised of open-ended probing questions that allow and enable the interviewee to share deeply held thoughts and beliefs about the key aspects of the situation identified in the expert model. This included consideration of:

- What people know about the risks and practice that is correct and essential to making an informed decision
- What people may misunderstand that is consequential
- What they do not know that is consequential
- What they want to know that is important to them
- What they know about the envisaged new practice
- What management's role is in addressing the risks
- What criteria they use to judge the trustworthiness and competence of people, organizations, and communications.

The guidance recognized that the aspect of confidentiality would be of crucial importance, as would be the requirement that all interviewees participate voluntarily in the interview process. These aspects were dealt with in the procedural guidance on setting up and conducting the enquiries.

Analysis of the interview responses in relation to an expert understanding of the risk situation then enables determination of relevant knowledge gaps, misperceptions and misbeliefs, and any other misunderstandings relevant to adoption of the selected leading practice in addressing the risk situation. Together, these elements become a statement of the prevailing mental model. Arriving at this statement does, however, involve a careful process of coding and collating the responses from all interviewees, and guidance was thus developed to assist the adoption teams in undertaking this work. Table V provides an indication of the format and content of a mental model empirically derived from such a process.

A secondary, but significant benefit associated with the direct enquiry process is that it meaningfully engages a number of persons directly involved in adoption of the leading practice. Realization of this benefit does, however, require the provision of meaningful feedback to those involved in the adoption process. Significantly, this requirement is effectively addressed through implementation of the behavioural communication and leadership behaviour plans considered below.

Preparation of generic behavioural plans

Once again, the process of preparing a behavioural communication plan proved to be a learning experience. Indeed, the first behavioural communication plans were prepared under the direct supervision of the collaborating consultants, Decision Partners. Based on their input, guidance to assist the adoption teams in the process for preparing behavioural communication plans was developed and included in the Handbook.

Having determined the prevailing mental models, the process involves the following three relatively simple steps:

- First, logically group the misperceptions, misunderstanding, knowledge gaps, and any other beliefs or considerations that would either facilitate or inhibit successful adoption of the leading practice
- Then, determine the implications of each of these beliefs as well as the information that needs to be successfully communicated to build on or address the identified implications
- Finally, develop a detailed behavioural communication plan that sets out who is to communicate what, and how, to ensure that the identified information reaches the intended recipients.

While the development of a generically applicable behavioural communication plan is undertaken by the relevant MOSH adoption team, the selection of persons to deliver the identified messages at the mine clearly needs to be a mine responsibility. This is an important responsibility, since selection of credible persons to deliver the identified messages is crucially important. The template provided in the Handbook for capturing a detailed behavioural communication plan is shown in Table VI.

Preparation of leadership behaviour plans

Although the enabling role of leadership was brought out in the original design of the system, the key role of leadership

Table V

Format and example content of an empirically derived mental model report

Major theme	Sub-theme	Description of theme	Summary of findings
Cause of falls of ground	Procedures	Procedures are not followed. This could be due to many barriers, such as worker skills or experience, cutting corners, supervision	This was the most significantly mentioned cause mentioned by about 75% of interviewees, representing all mine positions. Interviewees identified 'lack of barring' 'incorrect support', 'poor examination' *etc.*….
	Unforeseen		
	Technical		
Barriers or challenges to address	Skill	Worker skills / experience / expertise / qualifications / not adequate	This was the most commonly mentioned barrier linked to the cause of FOG. Skill was often linked to a lack of understanding of 'why' rather than 'what' or 'how'. For example: 'The people know how to bar but not why – they rush straight to the face and begin face preparation'. *Etc.*……
	Buy-in		
	Etc.		
The report goes on to cover a number other major themes, with each major theme having many sub-themes			

Table VI

Template showing details required in a behavioural communication plan

No.	Belief /issue being addressed	Recipient	Message / communication content	Mode (Meetings training briefings *etc.*)	Tools / means (Scripts presentations) theatre- *etc.*)	When	Responsibility for delivery	Who to ensure	Evaluation/ control measure
1									
2									
Etc.									

Table VII

Template showing details required in a leadership behaviour plan

Leadership levels Details of all relevant level of operation and leadership	Antecedents Things that are required to enable, prompt or precede delivery of identified key behaviours	Behaviour Key behaviours that are essential for successful adoption and operation of the practice	Consequences Actions to be taken to reinforce or discourage observed behaviour
Operator / technician			
First line supervisor			
Second level supervisor			
Third level supervisor			
Others, *etc.*			
Highest level manager			

behaviour, explicitly in the form of the well-known A-B-C concept (antecedent-behaviour-consequences), only emerged during the process of developing the behavioural communication plans.

In simple terms, the elements of the A-B-C concept are as follows:

- ***Antecedents*** are the things that prompt and enable behaviour, such as training, proper tools, briefings, *etc.*
- ***Behaviour*** is anything a person does or says, or fails to do or say, good or bad
- ***Consequences*** are actions or events, that follow exhibited behaviour, and that serve to reinforce or discourage the behaviour in question.

The concept, originally developed by Skinner (1952), has been adapted and used in various ways in industry (Scott Geller, 2005; National Mining Association 2016). Unfortunately, this has sometimes had counterproductive effects, particularly when used in the South African mining industry to identify unsafe behaviour by individuals, and thus to inadvertently apportion blame (Smith, 1999).

Consideration of the A-B-C concept by Decision Partners in the development of behavioural communication plans was thus unexpected, but was in retrospect entirely logical. The logical link between behavioural communication and the A-B-C concept lies in their similarity of purpose. Behavioural communication seeks to inform people to enable better decision-making, and thus more appropriate consequential behaviour in adopting a leading practice to address a prevailing risk situation. Similarly, the A-B-C concept seeks to equip people with the understanding and skills needed to undertake key tasks in operating and overseeing the leading practice being introduced. Significantly, the A-B-C concept also seeks to entrench those behaviours responsible for successful execution of the key operational and oversight tasks associated with ongoing successful operation of the practice. In essence, both therefore seek to equip people to voluntarily behave in appropriate ways in adopting a particular leading practice to reduce risk. Importantly, together, they serve as a means for securing eager, voluntary and sustainable adoption of an identified leading practice.

Based on the above understanding, guidance to assist adoption teams in the preparation of leadership behaviour plans was prepared. This included use of the direct enquiry and mental models process to assist in identifying content for inclusion in the leadership behaviour plans. Guidance was also provided on identification of the key technical and behavioural aspects of successfully operating the leading practice that needed to be addressed in the plan. The template developed for capturing a detailed leadership behaviour plan is shown in Table VII.

Particularly noteworthy aspects of such leadership behaviour plans include the following:

- Details are specified for all levels of operation and leadership that are crucial to successful adoption
- Securing provision of the required antecedents is a key behaviour of higher levels of leadership.
- The identified actions as a consequence of exhibited behaviour are key behaviours of higher leadership levels
- Consistently applied actions as a consequence of observed behaviour are crucial to achieving sustainable adoption
- The plan systematically specifies and integrates the actions of all persons needed to secure successful and sustainable adoption of the leading practice.

Customization of behavioural plans

As understanding of the principles and practicalities of behavioural communication grew, so too did concern about how best to take account of differences between mines. It was recognized that mines could differ quite significantly in both operational and management approach and culture, and that a generally applicable behavioural communication plan would therefore need to be adjusted to address significant mine-specific issues. A simplified direct enquiry and analysis process was thus developed to identify such issues, thus forming a basis for customizing the generic behavioural communication plans developed by the MOSH adoption teams.

An important consideration in developing the customization process was to keep it as simple and practical as possible for application at mines. A relatively simple direct enquiry process based on ten standard questions was thus designed. Although simpler, it still required 25 to 30 persons to be interviewed at the mine. Analysis of the interview responses was then similarly simplified to focus on identifying only those mine-specific issues not already covered by the generic behavioural communication plans. Appropriately, detailed guidance was prepared to assist mines in customizing the generic plans provided by the MOSH adoption teams.

The MOSH behavioural processes as a science-based system

As the above described understanding grew, it became increasingly clear that the various behavioural processes needed to be seen as parts of a coherent behaviour management system. It also became clear that together they gave practical effect to extensive scientific work on both mental models and human behaviour. Based on the above, and as depicted in Figure 7, the essential logic of the integrated system may be summarised briefly as follows:

- ***System logic***—*In any given situation a person's behaviour is guided by their mental model of that situation (for example, the adoption of a new practice to address an OHS risk). This mental model is determined by analysis of responses gained in a one-on-one semi-structured interview. Formulation of the open-ended questions used in the interview is guided by an expert understanding of the situation. This expert understanding, in the form of an expert model, is developed through a prior engagement process involving technical and operational experts. Key issues (knowledge gaps and misbeliefs) in the person's empirically determined mental model are identified by comparison with the expert model. Communication is then developed and used to address the identified mental model issues. In addition, behaviour essential to successfully address the given situation is identified from the expert understanding of the situation. Leadership behaviour needed to enable and sustainably achieve these essential behaviours is then identified and implemented.*

The science base of the integrated system is summarized briefly as follows:

- ***Science base***—*Since 1932, when the concept of a mental model was first defined, many scientific studies have been published (Wood et al., 2017). As described in detail by Morgan et al. (2002), such work provides the basis of the mental models elements of the system. Similarly, since Skinner published his basic work on human behaviour (Skinner, 1952), his concepts have been widely accepted and applied by others (Scott Geller, 2005; National Mining Association, 2016). This work provides the basis of the behaviour management elements of the system. Together, the elements on mental models and behaviour management constitute an integrated science-based system.*

The science-based behavioural processes described above can then be presented as an operational system, as shown in Figure 8.

Importantly, Figure 8 depicts the various behavioural processes as an integrated system designed to facilitate eager, voluntary, and sustainable adoption of a leading practice. This science-based integrated system of practical processes is an aspect of the leading practice adoption system that differentiates it from other processes of technological innovation.

Explanation and detailed guidance on practical implementation of all of the above behavioural concepts and processes is provided in the Handbook (Stewart, 2014).

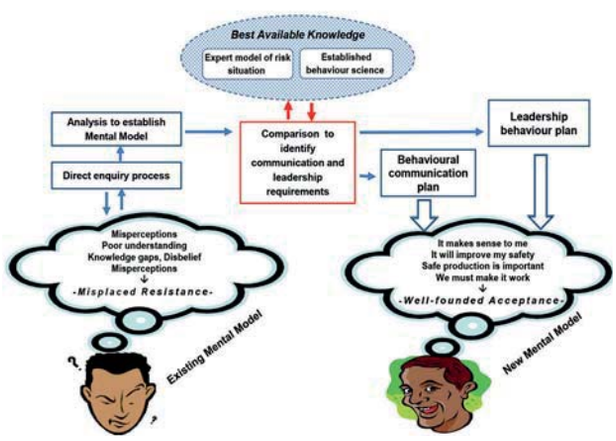

Figure 7—Schematic of factors involved in behaviour management

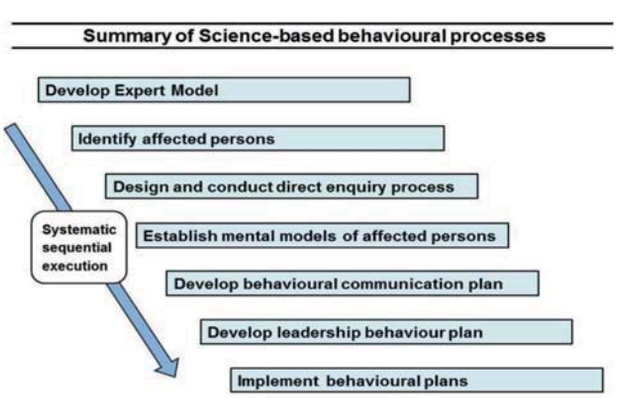

Figure 8—Schematic of essential MOSH behavioural processes

Key challenges in development of the overall system

Although development of the MOSH behavioural processes represented a major step forward, there were a number of other important developments in evolution of the overall system.

Communities of practice for adoption

In developing the guidelines for initiating and operating a successful community of practice for adoption (COPA), it soon became apparent that there was both a strong preference and need for the COPAs to operate in a much more structured manner than originally envisaged. In particular, a MOSH adoption team manager, serving as the COPA coordinator, needed to fulfil a number of key functions, as follows:

- Explaining the various adoption processes to COPA members
- Assisting mine adoption teams with implementation of the adoption processes
- Training or arranging training of mine persons in direct enquiry techniques
- Monitoring and reporting to industry on progress at mines in the adoption of leading practices
- Arranging presentations at COPA meetings to facilitate the exchange of adoption experience at mines
- Arranging and conducting regular COPA meetings to enable and sustain the adoption process.

Guidelines were accordingly developed and provided for the COPAs to be established and operated in this way. The key role of the COPAs in facilitating widespread adoption of leading practice soon emerged, particularly in respect of the COPAs established in the area dealing with falls of ground. In essence, the COPA harnessed, sustained, and directed the collective energy of a group of peers to acquire and apply the skills needed to secure successful adoption of a leading practice at their respective mines. In so doing the COPAs became the key means of effectively energizing and facilitating the widespread adoption of leading practice, and thus progress towards the achievement of zero harm. Fundamental to the establishment of a successful COPA was the identification and involvement of those people at potential adoption mines who would be central to deciding and enabling successful adoption of the practice at those mines. This key aspect of the process was emphasized in the guidelines that were developed, and in progress meetings of the adoption teams.

Process requirements at adoption mines

Notwithstanding the participation of mine representatives in COPA meetings, and the explanation and guidance provided during those meetings, the teams established at mines to manage adoption encountered a number of difficulties. Most of these difficulties were associated with the 'people aspects' of the adoption process, namely customization and implementation of the behavioural communication and leadership behaviour plans. In addition, the systematic requirements of the adoption process were not readily appreciated or implemented by the mine adoption teams. It soon became clear that there was a need for more detailed explanation of the concepts as well as the provision of more detailed guidance on execution of the various adoption processes.

These two needs were addressed by the MOSH adoption team leaders arranging for the various adoption processes to be explained in more detail during COPA meetings, and by the preparation of a more comprehensive guidance document for use by mines in adopting the leading practice. This guidance document, the 'Leading Practice Adoption Guide', sets out in detail each of the 16 steps for successfully adopting a particular leading practice at a mine. In addition to providing guidance on each of the 16 steps, the document provides the generic behavioural communication and leadership behaviour plans, as well as the technical details that have been developed for the leading practice. It is these three elements that are essential for successful and sustainable adoption of a leading practice. Without them the adoption is unlikely to be successful, and even less likely to be sustainable. These three elements are likened to the legs of a three-legged stool in that all three must be in place for a successful outcome. In addition to its intended use at adoption mines, the Leading Practice Adoption Guide also serves as a basic resource for use in COPA meetings. Guidance to assist the MOSH adoption teams in the preparation of these user-friendly documents for each of their leading practices was thus developed and included in the Handbook. The sixteen steps are shown later as part of the overall system that emerged.

Time scale of the process

One of the major problems that became increasingly apparent during the piloting process was the lengthy time delay between identifying the leading practice and making it available to mines for adoption. In essence, there were two reasons for this. The first was the time needed to document the identified leading practice at the source mine, to conduct the direct enquiry process and to then develop the required behavioural communication and leadership behaviour plans. All going well, this took about three to four months. The second was the time taken to demonstrate adoption of the leading practice at a selected 'demonstration mine'. This demonstration process, was partly to test the behavioural plans, but also to finalize the value case for the leading practice and to prepare a document to guide adoption at future adoption mines. Once again, all going well, this took another three to four months. In practice, the total delay period was thus between six and nine months. During this period the management at some mines became impatient and the potential for uninformed and unsuccessful adoption attempts became real. It was recognized that such attempts, in addition to being costly, could unjustly discredit both the leading practice and the adoption process.

Fortunately, based on growing experience and ongoing development of the process, it became apparent that it would be possible to provide a comprehensive generic draft of a 'Leading Practice Adoption Guide' to mines at the time the adoption team was ready to demonstrate adoption of the leading practice. This opened the way to shortening the process. By forming a COPA in parallel with initiating and facilitating adoption of the leading practice at a 'lead adopter mine', the adoption team could then use the COPA to ensure that other mines electing to adopt the practice in parallel were

kept abreast of any changes needed to the draft guide as a result of experience gained at this lead adopter mine. Facilitation of widespread adoption of the leading practice at other mines could thus proceed in parallel with the lead adopter mine. Furthermore, the lead adopter mine could be identified by the adoption team at an early stage, and it could in effect serve very much the same purpose as a demonstration mine. On completion of the adoption process at the lead adopter mine, the draft leading practice adoption guide could then be revised to fully take account of the experience gained. In addition to reducing the time scale by about four months, introduction of these adjustments also increased the importance and vibrancy of the COPA.

Simple leading practice

Another aspect of concern was that the time and effort required to document and secure adoption of a comparatively simple practice seemed unwarranted. Indeed, examination of the nature of some of these simpler leading practices revealed a strong case for developing a much quicker and simpler set of processes for such practices, particularly if their adoption involved few people and relatively little training. In considering such practices, the primary concern was nevertheless that the benefit of using behavioural communication and leadership behaviour techniques to secure successful and sustainable adoption should not be lost.

Fortunately, a review of the behavioural plans developed for different practices showed that a number of the elements in the plans were effectively common. This finding led to the proposal that instead of following the full process, these 'generic elements' could be applied to these simpler practices to achieve many, although not all, of the benefits expected from the development of practice-specific plans. This would considerably shorten and simplify the process. Accordingly, a set of criteria for the identification of practices that could be treated as 'simple leading practices' was developed, along with a set of procedures and guidelines for documenting and presenting the practice to potential adoption mines. Similarly, a set of simple procedures was developed to guide adoption of the practice at mines. The procedures included a formal review process to ensure that the simplified and shortened process was not inappropriately applied to more complex leading practices; or to situations where the full adoption process is considered necessary to achieve sustainable adoption. Following acceptance of the above proposal, detailed guidance on the processes was introduced into the Handbook.

Development of a credible value case

One of the key elements of any innovation process, and thus also of the Adoption System, is user awareness of the benefits expected to accrue from adoption of the innovation in question. Development of a credible statement of these benefits thus became a fundamental consideration in both selecting and presenting a leading practice for adoption. Importantly, it provides key information for communication to mine management to enable and assist them in making a well-founded decision about whether to adopt the leading practice at their mine.

However, it was recognized that some of the important benefits of adopting a leading practice could be qualitative and not readily reduced to a simple financial business case. Accordingly, consideration was given to developing a much broader value case for adoption of a leading practice at a typical adoption mine, as opposed to the more usual business case. The guidance developed for preparing such a value case thus included consideration of qualitative benefits not readily expressed in financial terms. It also included an assessment of the extent to which the benefits might vary between mines, as well as an estimate of the collective benefit to industry should all of the identified potential adoption mines elect to adopt the practice.

Notwithstanding the long experience of adoption team managers in conducting cost-benefit assessments of projects at mines, preparation of the envisaged value cases for the various leading practices proved to be difficult. This was largely due to difficulties in acquiring the required information for a 'typical adoption mine', let alone for mines on either side of such a mine in the benefit spectrum. It was, however, also due to the difficulty and discomfort of taking qualitative assessments into account in developing the value case. It has been shown that such fundamental changes in approach take a lot of cognitive effort (Kahneman, 2011). Unfortunately, development of value case statements of the envisaged detail and quality remains a challenge.

Contrary to expectations, this shortcoming appears not to have hindered the process of achieving widespread adoption of the selected leading practices. Instead, it appears that the compliance requirements of the Mining Charter have had a strong effect in securing adoption uptake. Unfortunately, however, in the long term, adoption motivated in this way is likely to have a counterproductive effect. Indeed, mine management is likely to become increasingly resistant to participating in structures that identify leading practices that carry Mining Charter obligations. The long-term consequences of such tendencies, which are already beginning to appear, would be disastrous. These tendencies clearly need to be reversed. The achievement of sound value case statements is thus an issue that requires further investigation, as such statements provide a sound basis for both the selection and voluntary and eager adoption of a leading practice.

The need for early behavioural communication

Allied to the above is another important point, namely the need for early behavioural communication with managers at identified potential adoption mines. Unfortunately, the need for implementing a special behavioural communication plan to ensure that mine managements are fully informed about the leading practice, as well as the adoption process, before they decide whether to adopt was initially not properly recognized. However, it was eventually realized that such a communication plan was needed to address any possible misperceptions and knowledge gaps that could be material to management making a well-founded decision about the leading practice. Clearly, misperceptions or inadequate understanding and knowledge about a practice or the adoption process may exist at all levels and in all people. Having recognized this key point, it was equally clear that for each leading practice, an appropriate behavioural

communication plan needed to be developed and implemented as soon as possible by the adoption teams. Accordingly, development and application of a behavioural communication plan for a leading practice was adjusted to become a two-pronged process. In particular, the direct enquiry questionnaires were adjusted to include a section addressed primarily to 'deciders' (those responsible for deciding about adoption of the practice) and the analysis of interview responses was structured to yield two mental model reports. The first dealt with the group at the mine responsible for deciding to adopt the leading practice, and the second with all persons at the mine, at all levels, who are key to securing successful operational adoption of the practice. These two reports then formed the basis for developing the required two behavioural communication plans. Guidance in the Handbook was similarly updated to reflect this two-pronged process.

The developed MOSH adoption system

It will be apparent from the above that the MOSH Leading Practice Adoption System, as documented in the Guidance Handbook, is very different from that put forward in the original proposal in 2007. Notwithstanding its incremental development path, and the volume and detail of its documented processes, the logic and essence of the current MOSH Leading Practice Adoption System can nevertheless be presented in a single graphic. This is shown in Figure 9. With regard to Figure 9, it must be noted that it is the MOSH adoption teams, with support from specialists within the Learning Hub in using the guidance provided, that take responsibility for implementing the 15 processes shown. The more complex detail is thus dealt with by trained specialists and not persons at mines.

Regarding the adoption process at mines, which is the responsibility of individual mines, guidance for mines in their adoption of a leading practice is provided in the relatively brief user-friendly documents prepared by the MOSH adoption teams for each leading practice. The MOSH adoption teams are required to ensure that these Leading Practice Adoption Guides are suitably user-friendly and that they properly take account of mine and practice-specific issues. The 16-step adoption process that they outline in detail for use by mines is shown in Figure 10.

The logic and essence of the entire MOSH Leading Practice Adoption System is thus summarized in Figures 9 and 10, with detailed guidance for proper execution of the various processes being outlined in the Handbook (Stewart, 2014). This guidance is extensive, but the challenge of achieving eager voluntary adoption is not simple.

Discussion

The Leading Practice Adoption System has undergone a lengthy development process with much being learned along the way. Many have benefited from this learning process, at mines, in the Learning Hub, and in the mining industry in general. Importantly, in addition to the benefit of greater understanding and more effective processes, there appear to have been significant OHS-related benefits.

OHS impact of the adoption system

Firstly, there is the direct benefit to mines and industry from the adoption of leading practices, particularly in the area of falls of ground. Leading practices presented for adoption by 2013 are listed in Table VIII. In each case, the leading practice was selected because of its potential to achieve progress toward the goal of zero harm.

The adoption of such leading practices has been described in many unpublished internal and conference presentations, but there is unfortunately a lack of published data on the OHS improvements at mines following the adoption of a particular practice.

Secondly, there is the participation by many mining industry persons in the oversight and operational structures of the Adoption System. Their participation contributed towards a well-directed increase in the focus on health and safety issues across industry. A similar comment applies to the participation of mine staff in the various COPAs and in the adoption processes at mines. Importantly, along with other factors discussed below, this increased focus on OHS

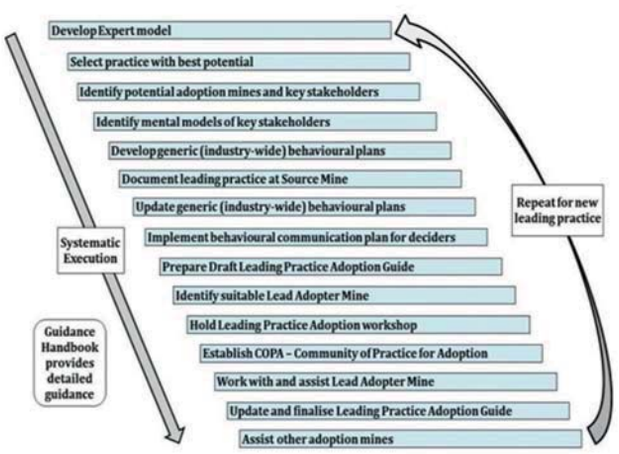

Figure 9—Major process steps of the MOSH Leading Practice Adoption System

Figure 10—16-step process for adoption of a leading practice at a mine

Table VIII

MOSH leading practices presented for adoption by 2013

Falls of ground

- *Entry examination and making safe*—A procedure involving the entire team in making the workplace safe, and in formally agreeing that this has been done, before work starts.
- *Nets with bolting*—Installation of nets attached to roofbolting to prevent falls of ground in areas where men are working.
- *Trigger Action Response Plan* (TARP)—A systematic check of known hazards in the workplace against predetermined risk criteria to trigger a planned response, escalated to the necessary level of authority until safety is restored.

Transport and machinery

- *Proximity detection systems*—Electronic systems installed on trackless and railbound equipment to detect nearby workers and/or beacons and equipment to prevent collisions and injury.

Noise

- *Hearing protection device selection tool and awareness training material*—A software package to enable optimal selection of HPDs for particular exposure situations, and communication and training materials to enable their effective use in practice.

Dust

- *Fogger/mist sprays*—The use of nozzles to create a mist of water droplets below 7 µm in size to enable the capture of airborne respirable dust particles in selected locations.
- *Footwall and sidewall treatment – Simple Leading Practice*—A practical procedure of wetting the foot- and sidewall with water and surfactants to consolidate the dust and prevent it from becoming airborne.
- *Multi-stage filtration system – Simple Leading Practice*—Provides filtration efficiencies of ≥98.5% at 0.5 µm and larger size particles discharged into air routed through an orepass.
- *Scraper winch cover – Simple Leading Practice*—A cover is fitted over the operating drums of a scraper winch to reduce the harmful dust exposure experienced by winch operators.

appears to have contributed significantly to the safety improvements achieved by industry since agreement to the 2013 milestones in 2003. These improvements are illustrated in Figure 11.

Compared with the minimal safety improvements achieved in the previous 15 years, as shown in Figure 1, Figure 11 shows a remarkable change in the nature of the safety performance trends after about 2001–2003. Agreement to the milestones in 2003 and the observed significant shift towards improved safety performance in all mining sectors are thus coincident in time. Although some of this improvement may be attributed to the adoption of new technology at some mines, it is likely that most of the improved performance following agreement to the milestones was due to the increase in focus on OHS issues by mine managements, organized labour, and the inspectorate.

However, it should be noted that the improvement in OHS performance was not always continuous. Figure 11 shows that safety performance in the gold sector deteriorated over the years 2004 to 2007, and in the coal sector from 2007 to 2008. However, the focus of top-level management on OHS was demonstrated in 2005 when CEOs of the major mining companies made a public commitment for their companies to achieve the 2013 milestones, and ultimately, the goal of zero harm. It was this commitment that led to the establishment of the High-Level Task Force in 2005, and development of the initial Adoption System proposal in 2007. The period of deteriorating OHS performance in the gold mining industry from 2005 to 2007 was thus accompanied by a steady increase in focus on OHS issues in mining companies at the highest level. Figure 11 shows that since 2007 there has been a relatively steady improvement in safety performance in all mining sectors.

Notwithstanding the logic of the above arguments, it must be recognized that many other factors have also contributed to the significant safety improvement shown in Figure 11. These include:

- ➤ Increasingly stringent enforcement by the Mine Health and Safety Inspectorate
- ➤ Implementation of various safety initiatives at individual mines
- ➤ Widespread introduction of MOSH leading practices at mines
- ➤ Introduction of leading practice reporting requirements in the Mining Charter
- ➤ Increased focus and cooperative participation by management and employees on achieving improved OHS.

Unfortunately, it is not possible to realistically quantify these separate contributions. However, in respect of the Adoption System's contribution, it is appropriate to note that one of the primary purposes in the design of the Adoption System was to secure the direct involvement and buy-in of key mining industry personnel. In practice this involved not only key high-level persons in all major mining companies, but also all key stakeholders and operational persons involved in more than 250 leading practice adoption processes across more than 55 major mines. Through participation in the oversight and operational structures of the Adoption System, including the various COPAs, and then also the many MOSH adoption processes implemented at mines, the number of persons directly involved in the Adoption System is numbered in thousands. Importantly, the majority of the persons involved in the adoption process at mines would have been exposed to, and affected by the

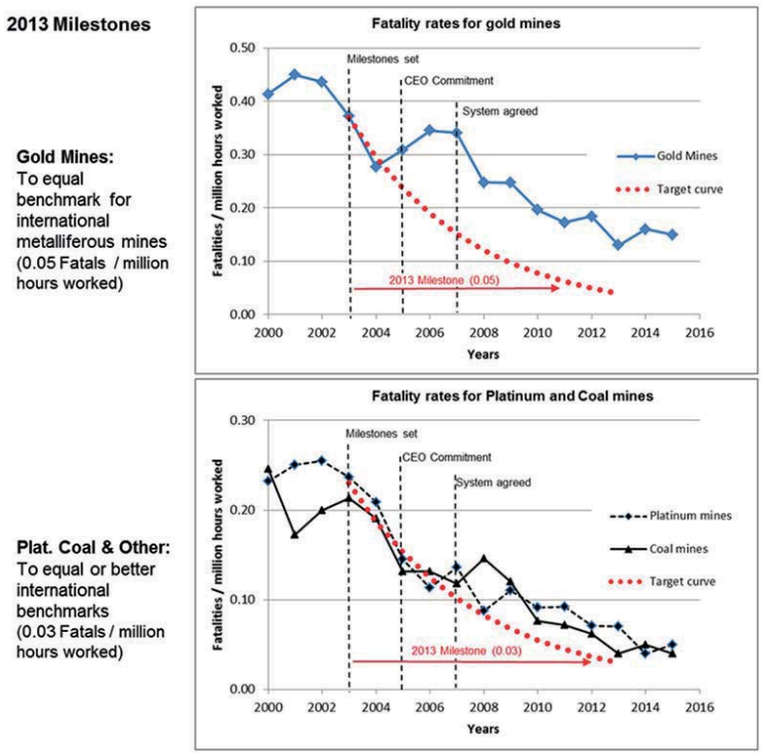

Figure 11—Mining industry safety improvements since setting milestones in 2003

behavioural messages communicated to them as part of the leading practice adoption process. In particular, these messages would have helped individuals improve not only their leadership behaviour but also their operational on-the-job risk assessments and the quality of their consequential behaviour.

User resistance

Notwithstanding the positive effect considered above, it appears that the behavioural processes, which are such an important aspect of the Adoption System, are considered by operational management at some mines to be too detailed and time-consuming, and to require expertise not available at the mine. In particular, many technical persons at the mines did not readily relate to the behavioural processes of the Adoption System. Furthermore, many mines already had their own processes for managing change. This has resulted in resistance at some mines, with some deciding to implement MOSH leading practices without applying the MOSH behavioural processes. This short-cut has become known as *implementation* of a MOSH leading practice, as distinct from *adoption*, which applies when the MOSH behavioural processes are properly used.

In retrospect, this resistance is not surprising, given that the MOSH behavioural processes were introduced in the period 2008-2011 without any systematic attempt being made to identify and address the resistance factors that would inevitably be present. Unfortunately, at that time, a full appreciation of the behavioural processes was simply too new for it to be recognized that the very processes being introduced into the Adoption System should have been used for their own introduction to industry. Ironically, they are the very processes that would have enabled identification of the knowledge gaps, misperceptions, and other barriers that needed to be addressed. They would also have yielded an appropriate behavioural communication programme to address the identified barriers. In regard to this important realization, it is worth noting that over time it had become apparent that many key persons had an inadequate familiarity with and understanding of the adoption system. This was confirmed through a direct enquiry investigation. However, although an informative video was produced in an attempt to address the issue (MOSH, 2014), the full extent of the shortcoming only emerged later.

Noting the different approaches to adoption explained above, the Culture Transformation Framework established for the mining sector (MHSC, 2011) called for a common approach to identifying and facilitating the adoption of leading OHS practices and research outcomes. In response, the Mine Health and Safety Council recently developed, with input from the Learning Hub, a brief generic guideline for identifying and facilitating the adoption of leading OHS practices (MHSC, 2016). Importantly, the guide is in essence consistent with the requirements of the MOSH Adoption System, although it does not provide the same level of process detail. Instead, in the areas covered by the MOSH behavioural processes it simply requires the use of recognized and valid processes. Inescapably, therefore, it appears that the need to address resistance to the use of such processes, be they from MOSH or elsewhere, still needs to be addressed. This matter is currently being considered within the Learning Hub.

Effectiveness of the system

Much like the strength of a chain, the effectiveness of the Adoption System is determined by its weakest element. This is particularly true in respect of behavioural communication, starting with development of the expert model right through to development and delivery of the behavioural communication plan. It is thus important that the specialists within the Learning Hub guard against the possibility that execution of the various processes becomes in practice an ineffective box-ticking exercise.

In this regard there is an aspect of the behavioural communication process that requires particular attention, namely development and testing of the detailed communication material. While the format of the behavioural communication plan shown in Table VII clearly sets out all its key elements, it does not directly contain the detailed communication material. The brief statement in the plan of the message to be communicated generally falls far short of what is needed to effectively convey the identified message. To be fully effective, the behavioural communication material needs to include detail that is credible and readily understood by the intended recipients. Importantly, the prepared material and the manner of its presentation need to be tested to ensure their effectiveness. This, however, can be costly, time-consuming, difficult, and thus inhibiting.

Increasingly, it has been recognized that the behavioural communication material being used at mines generally falls short of what is required for it to be fully effective. Although the importance of this point has been emphasized, and guidance on the preparation of effective communication material strengthened, it appears that this remains an area of weakness. It is thus an issue that warrants further attention. Continued weakness in this area will compromise the effectiveness of not only the behavioural processes, but ultimately, also the credibility and use of the Adoption System.

A leading practice in its own right

Given the sound basis of the Adoption System, and the key behavioural aspects that differentiate the system from other ways of securing technology transfer and innovation, it has been recognized as a leading practice in its own right. This point was made in 2013, in a presentation to industry representatives at the annual Mine Health and Safety Conference held in South Africa (Malatji and Stewart, 2013). It was later also recognized by the US Army Corp of Engineers in their published review of mental models technology (Wood, 2017), when they decided to include a chapter on the Adoption System (Stewart and Butte, 2016). Importantly, as pointed out in the Handbook, the MOSH Leading Practice Adoption System is a system that can be readily adapted for use in other settings.

New goals and priorities

While establishment of the milestones in 2003 marked the start of a remarkable period of occupational safety improvement in the South African mining industry, a similarly strong improvement is not readily evident in the area of occupational health. This is disappointing, given the major need for improvement in the areas of silicosis and noise-induced hearing loss. Unfortunately, the priority given to addressing these issues has not been as intense as it should have been, perhaps because the consequences of unsafe exposure to dust and noise are usually not

Table IX

New OHS milestones agreed in 2014 - the road to zero harm

Area	Agreed milestones
Fatalities and Injuries	• Every mining company must have a target of ZERO fatalities. • Fatalities to be eliminated by 2020. • Up to Dec. 2016, serious injuries to be reduced by 20% per annum. (Not achieved - 15% achieved in 2016) • From Jan. 2017 onwards, lost time injuries to be reduced by 20% per annum.
Occupational lung diseases	• By Dec. 2024, 95% of all exposure measurements of respirable crystalline silica to be below 0.05 mg/m^3. • By Dec. 2024, 95% of all exposure measurements for platinum dust respirable particulate to be below 1.5 mg/m^3, and < 5% crystalline silica. • By Dec. 2024, 95% of all exposure measurements for coal dust respirable particulate to be below 1.5 mg/m^3, and < 5% crystalline silica. • Using present (2014) diagnostic techniques, no new cases of silicosis, pneumoconiosis, coal worker's will occur amongst previously unexposed individuals.
Noise-induced hearing loss	• By Dec. 2024, total operational or process noise emitted by any equipment must not exceed a sound pressure level of 107 dB(A). • By Dec. 2024, no employee's Standard Threshold Shift will exceed 25 dB from baseline when averaged at 2000, 3000, and 4000 Hz in one or both ears. • Establish a multi-stakeholder team to consider different compensation systems.
TB and HIV AIDS	• By Dec. 2024, TB incidence rate to be at or below the National TB incidence rate. • 100% of employees to be offered HIV counselling and testing annually with all eligible employees linked to an anti-retroviral therapy programme as per the National Strategic Plan.
Culture transformation	• By 2020 there will be 100% implementation of the following Pillars of the Culture Transformation Framework: Leadership, Risk Management, Bonus and Performance Incentive, Data Management, Diversity and Leading Practice. • After 2020, the remaining pillars of the framework will be implemented, namely: Integrated Mining Activity, Technology, Inspectorate, and Tripartism and Regulatory Framework.
Centre of Excellence	• Launch Centre of Excellence, undertake quick-win projects, and implement technology and knowledge transfer of quick-win projects. • Centre of Excellence to be operational by 1 April 2016. (Scheduled for November 2017)

immediately apparent, and may take many years to develop. However, the need to effectively address the health challenge has been increasingly recognised across industry. The CEO Zero Harm Task Team established by employers is focused equally on health and safety, and the new OHS milestones that were agreed to by the tripartite partners in 2014 (MHSC, 2014) have a clear focus on key health issues. A summary of these milestones is presented in Table IX.

Conclusion

A key point brought out in this paper is the value of a holistic systems approach when addressing a multifaceted issue such as occupational health and safety. In particular, such an approach provided insightful guidance in developing a climate conducive to innovation; it proved to be fundamental to understanding the behavioural processes of the Adoption System, and it underpinned the design and development of the adoption system. Indeed, in retrospect it is appropriate to recognize that the significant OHS improvements reported in this paper stem from the combined effect of the Leon Commission of Enquiry, the ILO Convention on Safety and Health, the Mine Health and Safety Act and its structures, establishment of the tripartite agreed OHS milestones, the initiatives of individual mines, and development and implementation of the MOSH Leading Practice Adoption System. Finally, in regard to the system, it has become abundantly clear that managing behaviour change is not a simple matter, that this challenge cannot be made simpler than it is, and that short-cuts will be counterproductive in the long-term.

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References

Butte, G. 2007. Expert model of innovation. Decision Partners LLC, Pittsburgh, USA. Personal communication.

Decision Partners. 2008. Adoption planning process workbook and resource kit. Decision Partners LLC, Pittsburgh, USA.

Gouws, M.J. 2004. Review of industry health and safety performance. Chamber of Mines of South Africa, Unpublished document. Personal communication.

Harrington, J.S., McGlashan, N.D., and Chelkowska, E.Z. 2004. A century of migrant labour in the gold mines of South Africa. *Journal of the South African Institute of Mining and Metallurgy*, vol. 104, no. 2. pp. 65–71.

Hermanus, M., Coulson, N., and Pillay, N. 2015. Mine Occupational Safety and Health Leading Practice Adoption System (MOSH) examined – the promise and pitfalls of this employer-led initiative to improve health and safety in South African Mines. *Journal of the Southern African Institute of Mining and Metallurgy*, vol.115. pp. 717–727.

Kahneman, D. 2012. Thinking, Fast and Slow. Penguin Books.

MAC, 2003. A field guide for building shared understanding for: Towards Sustainable Mining. Mining Association of Canada.

Malatji, S and Stewart, J.M. 2013. The MOSH Leading Practice Adoption System: A leading practice in its own right. *Proceedings of Minesafe 2013*, Johannesburg, 22–23 October. Southern African Institute of Mining and Metallurgy, Johannesburg.

MHSC. 2003. Milestones of the 2003 Mine Health and Safety Summit. http://www.dmr.gov.za/mine-health-a-safety.html

MHSC. 2011. The culture transformation framework. Mine Health and Safety Council, Johannesburg. http://www.mhsc.org.za/sites/default/files/Final Document - The Culture Transformation Framework 2011.pdf

MHSC. 2014. Mine Occupational Health and Safety Summit – The Road to Zero Harm – New Milestones. Mine Health and Safety Council, Johannesburg.http://www.mhsc.org.za/sites/default/files/Mr%20Msiza%202014%20Milestones_0.pdf

MHSC. 2016. MHSC guideline for the identification and adoption of leading OHS practices. Mine Health and Safety Council, Johannesburg.

Morgan, M.G., Fischoff, B., Bostrom, A., and Atman, C.J. 2002. Risk Communication – A Mental Models Approach. Cambridge University Press, New York, USA.

MOSH. 2014. MOSH leading practice adoption system video. http://www.mosh.co.za/mosh-leading-practice-adoption-process.

NACI. 2003. Utilisation of research findings – Extent, dynamics and strategies. National Advisory Council on Innovation.

National Mining Association. 2016. Handbook about CORESafety and Health Management System. http://nma.org/wp-content/uploads/2016/09/CORESafety-Handbook.pdf.

Scott Geller, E. 2005. Behaviour-based safety and occupational risk management. *Behaviour Modification*, vol. 29, no. 3. pp. 539–561.

Skinner, B.F. 1952. Science and human behaviour. BF Skinner Foundation. http://bfskinner.org/store

Smith, T.A. 1999. What's wrong with behaviour-based safety? *Professional Safety*. September. pp. 37–40

Smith, M.K. 2003. Communities of Practice. *The Encyclopedia of Informal Education*. www.infed.org/biblio/communities_of_practice.htm

Stewart, J.M. 1982. Practical aspects of human heat stress. *Environmental Engineering in South African Mines*. Mine Ventilation Society of South Africa. Johannesburg. pp. 535–567.

Stewart, J.M. 1995. The role of legislation and regulation in health and safety in mines. *Journal of the South African Institute of Mining and Metallurgy*, vol. 95, no. 2. pp. 91–100.

Stewart, J.M. 2004. Historical background to levies and SIMRAC. Report submitted to Mine Health and Safety Council.

Stewart, J.M. 2007a. From sharing to widespread adoption of technology and best practice to improve occupational health and safety in mines. Report submitted to the Chamber of Mines of South Africa [reproduced in full in Stewart, 2014].

Stewart, J.M. 2007b. Key concepts and insights from past work on technology transfer. Report submitted to the Chamber of Mines of South Africa.

Stewart, J.M. 2014. MOSH Leading Practice Adoption System Guidance Handbook. Chamber of Mines of South Africa. http://www.mosh.co.za/hub/handbook

Stewart, J.M. and Butte, G. 2017. The Chamber of Mines of South Africa Leading Practice Adoption System. *Mental Modelling Approach – Risk Management Case Studies*. Wood, M.D., Thorne, S., Kovacs, D., Butte, G., and Linkov, I. (eds). Springer, New York, USA.

The Distance Consulting Company. 2000. Community of practice start up kit. http://www.srpc.ca/ess2016/summit/copstartupkit.pdf

Van der Woude, S., Stewart, J.M., Ally, I., and Leburu, T. 2005. Strategies for sustainable safety improvements in South African mines. *Proceedings of the NOSHCON Conference on Occupational Health and Safety*, Sun City, South Africa, 4–7 April.

Van Zyl, A. 2010. Mining Industry occupational safety and health process for the adoption of leading practices. *Proceedings of the Second Hard Rock Safe - Safety Conference*, Johannesburg, 4–6 August. Southern African Institute of Mining and Metallurgy, Johannesburg.

Wenger, E. 1998. Communities of Practice: Learning, Meaning and Identity. Cambridge University Press.

Wood, M.D., Thorne, S., Kovacs, D., Butte, G., and Linkov. I. 2017. Mental Modelling Approach – Risk Management Case Studies. Springer, New York, USA.

Wyndham, C.H. 1974. Research on the human sciences in the gold mining industry – 1973 Yant Memorial Lecture. *American Industrial Hygiene Association Journal*, vol. 35. pp. 113–136. ◆