A NEW APPROACH INTRODUCING STANDARDS INTO MAINTENANCE DEPARTMENT GUIDELINES IN SMES IN ISRAEL TO IMPROVE SAFETY.

A Multi-Grounded Action Research Study with Maintenance Departments' Workforce Members, Managers and Safety Officers

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By Avishai Rash

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ABSTRACT

Title: A New Approach Introducing Standards into Maintenance Department Guidelines (Toolboxes and RAMS) in SMEs in Israel to Improve Safety: An Action Research Study with Maintenance Departments' Workforce Members, Managers and Safety Officers [Short Title: Study Introducing Standards into Maintenance Work Guidelines].

This study focusses on the link between accidents in different types of Small and Medium sized Enterprises (SMEs) and the lack of inclusion of published standards in work-guidelines (referred to in the trade as tool boxes and risk assessment methods statements - RAMS) used by workers responsible for the maintenance of those buildings. Using an approach of Multi-Grounded Action Research, combining existing theories on knowledge management and their provocative use, together with carefully conducted interviews on the ground, a more thorough understanding of what takes place in practice in maintenance departments was attained. The action research approach helped gain the cooperation of maintenance managers who could give their input in interactive coaching sessions, and contribute towards improving and eventually resolve the commonest problems causing accidents. As a result of the findings of the first phases of action research, the focus of study was extended to include assessment of the comprehension and implementation of safety standards for maintenance work. This was followed by further coaching sessions to improve comprehension and implementation of these crucial safety regulations in practice in SME maintenance departments in Israel.

The study is divided into three parts. The first part collects and collates recently published standards (since the year 2000) applicable to work-guidelines used in SMEs' maintenance departments related to safety, energy efficiency, environmental protection and risk management. The second part of the study based on multi-grounded action research and provocative theory identifies which elements from regulations included in published standards are, in practice, not included in work guidelines of maintenance departments; or if included are not implemented and WHY that is the case. The interviews with personnel and interactive coaching sessions that followed revealed that the main reasons for critical information from standards not being included in maintenance department work-guidelines and/or not implemented was found to be that not only are these regulations written in complex language employing many technical terms, but they are also scattered through many different publications and not easily accessible. Safety personnel and supervisors cannot write proper tool boxes and RAMS guidelines including all relevant information from standards if they cannot access this information and cannot understand what the instructions mean, when they do access it. The third part of the study therefore involved interactive coaching sessions with maintenance managers aimed at improving the comprehension of those regulations not properly understood and therefore not implemented. The aim was to rectify the current widespread inattention to safety regulations.

Each part of the study involved tabulation of the findings in a way that would provide tools for use in maintenance departments and in further studies. The first part of the study involved tabulating the essential information from published safety standards for various maintenance tasks in general and essential information for particular maintenance professions in an accessible manner. The compilation of the Table of Standards Relevant for Maintenance (TOSSREMs) provides essential knowledge to SME departments. As a result of the action research in the second stage of the study, appendices were added to these tables to include explanations of the regulations in simple, easily comprehensible language so that all critical information would be easily accessible to maintenance professionals.

During the second part of the study during the Action Research, the Compliance with Standards Relevant to different Professionals was assessed when looking at answers to interview questions. Any company or research body wishing to assess compliance with TOSSREMs may follow the same methodology. Building COMPTRAP tables (compliance with Standards relevant to professionals) enables researchers to identify which standards are not understood by maintenance professionals, and therefore not implemented in the day-to-day work of these departments, indicating that coaching sessions explaining and working on comprehension of these standards' may be essential to ensure proper safety regulations are being followed. Coaching was found to be the best methodology for ensuring safety improvements in the field.

The third stage of the study involved coaching sessions specifically designed to help improve working comprehension and implementation of regulations identified as problematic in the second stage of the study. Interactive coaching sessions were found to be the best methodology for ensuring safety improvements in the field, with passive training sessions or lectures not found to be effective. Following the first round of coaching sessions, rephrased explanations of the standards were added as supplementary explanations to all of the TOSSREM tables. Repeated interviews revealed that using these tables with the supplementary material in conjunction with work guidelines could ensure that essential information from standards would be firstly be included in work guidelines in a more comprehensible way and secondly (and more crucially) would be implemented, rather than being ignored.

Thus, through working together with maintenance team leaders, the action research attempts to use the knowledge accumulated to reduce the incidence of serious accidents related to maintenance work in SMEs. One way to ensure the success of the research design was by adopting a reverse engineering methodology to the action research. This meant starting with the desired end result, of personnel being familiar with, understanding and implementing the relevant published standards which would prevent or at least reduce the incidence of accidents related to maintenance work. Working backwards from this desired end point, questionnaires

assessed how far the current situation deviated from there, and what could be done to narrow the gap. The novel reverse engineered double loop method developed in this study, ensures crucial information from standards and regulations is included in work guidelines **before** work is started on any maintenance project.

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LIST OF ABBREVIATIONS

ANSI	American National Standards Institute
CDC	Centers for Disease Control and Prevention
CIT	Critical Incident Technique
COMTRAP	Compliance with Table of standards relevant for maintenance professionals
ECDC	European Centre for Disease Control and prevention
EMS	Environmental Management Systems
ESAW	European Statistics on Accidents at Work
HSE	Health and Safety Executive
IBDO/MATI	Israeli Business Development Organization
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronic Engineers
ILO	International Labour Organization
ISO	International Organization for Standardization
KM	Knowledge Management
MGAR	Multi Grounded Action Research
OHS	Occupational Health and Safety
RAMS	Risk Assessment Method Statements
RCM	Reliability Centred Maintenance
SECI Model	Socialization, Externalization, Combination, Internalization
SME	Small and Medium Sized Enterprise
SSM	Soft systems methodologies
TOSSREM	Table of Standards relevant to maintenance work

TPM Total Productive Maintenance

TPeM Total Performance Management

TQM Total Quality Management

DEDICATION

I dedicate this thesis to my wife, to whom I cannot begin to express my thanks, who I love everyday more than the previous one, who was a constant support to me during all of this journey.

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First, I would like to thanks my final supervisor Dr Caroline Ramsey who gave me enough self-confidence to continue writing this thesis, and without knowing each other, together with my wife, enabled me to finalize this writing.

Then I would like to thank my English editor who had to confront my Hebrew English writing and translate it to proper English.

AUTHOR'S DECLARATION

The principal researcher, Avishai Rash, hereby declares A New Approach Introducing Standards into Maintenance Department Guidelines (Toolboxes and RAMS) in SMEs in Israel to Improve Safety: An Action Research Study with Maintenance Departments' Workforce Members, Managers and Safety Officers [Short Title: Study Introducing Standards into Maintenance Work Guidelines] to represent original research that has not been submitted previously for publication. The researcher served as the sole author for the study, which was completed under the thesis supervision of Dr Caroline Ramsey as a requirement for the degree of Doctor of Business Administration from the University of Liverpool. When drawing upon the work of others within the existing literature, the principal researcher has provided appropriate referencing and acknowledgment to the sources.

There was no direct funding source for the Study. However, the principal researcher works in the field of engineering and his consulting company provides partial tuition reimbursement to employees who are pursuing higher education. While Israel SME association did not fund the study in a direct manner, the organization awarded tuition reimbursement on an annual basis to offset a small portion of tuition costs.

CHAPTER 1 INTRODUCTION

Maintenance: The combination of all technical and associated administrative actions intended to retain an item in, or restored it to a state in which it can perform its required function. British Standard (BS3811-1984)

1.1 Introduction to the research and the origins of the study

The main motivation behind this study into the implementation of standards in maintenance department work guidelines is my wish to prevent accidents caused by maintenance work that does not conform to safety standards. Working as a maintenance consultant, I had been aware for some time of the rising numbers of accidents in Israel related to maintenance work since around the year 2000 (Zeiler, 2003; Reason & Hobbs, 2003).

1.1.1 The wider context of the study: An unacceptable situation

In 2008, the International Labour Organization (ILO) issued the second edition of its guide to the fundamental principles of Occupational Health and Safety (OHS) (Alli, 2008 p.3 -4). Its overview summarized the gravity of the current situation, "The human, social and economic costs of occupational accidents, injuries and diseases and major industrial disasters have long been cause for concern at all levels from the individual workplace to the national and international. … A recent ILO report estimated that 2 million occupational fatalities occur across the world every year." Furthermore, "according to the European Statistics on Accidents at Work (ESAW), every year in the 15 Member States of the European Union (EU) before the enlargements of 2004 and 2007 about 5,000 workers were killed in accidents at work and about 5 million workers were victims of accidents at work leading to more than three days' absence from work. In India and China, the rates of occupational fatalities and accidents are similar at, respectively, 10.4 and 10.5 per 100,000 for fatalities, 8,700 and 8,028 for accidents. In sub-Saharan Africa, the fatality rate per 100,000 workers is 21 and the accident rate 16,000. This means that each year 54,000 workers die and 42 million work-related accidents take place that cause at least three days' absence from work. In Latin America and the Caribbean, about 30,000 fatalities occur each year and 22.6 million occupational accidents cause at least three days' absence from work". As the title of their overview chapter states, this is an unacceptable situation.

These statistics underpin the urgency of research that may lead to changes on the ground. As will be discussed further chapter two, theoretical knowledge is not always readily disseminated efficiently, and not necessarily implemented in practice. This study attempts to use action research to bring regulations contained in standards into practice on the ground through their inclusion in an understandable and accessible way into work guidelines, thereby effecting change in safety behaviours in maintenance departments. While some hazards relate to natural disasters, which may not be avoidable, current Health and Safety theories relate to man-made disasters. Analysis of these disasters indicate a lack of foresight which led to an accumulation of latent errors; the so-called 'disaster incubation model' (Pidgeon & O'Leary 2000). It is the thesis of this study that the inclusion of directives contained in safety and risk analysis standards in daily work guidelines of maintenance departments would reinforce foresight, much in the same way as aircraft pilots go through a safety checklist before each and every time they take off.

1.1.2 Accidents in Small and Medium Sized Enterprise (SME) maintenance departments.

My initial review of accident investigation reports revealed long lists of regulations found in published standards which, had they been followed, would have helped avoid the accidents (Ra'anan et al., 2016; Gittelson et al., 2016). The study is intended to create a fuller understanding of the problem, yielding the knowledge necessary to initiate broad changes in workplace practices in Small and Medium Sized Enterprise (SME) maintenance departments. Despite the growing public concern and widespread media attention given to these accidents, there has been, as yet, little or no scholarly research into the implementation of published safety standards in maintenance departments.

The idea to carry out research into this field started as far back as November 2002, when I participated in a Medpower Conference (Mediterranean conference on power generation, transmission, distribution and energy conversion), held in Athens, Greece, attended by engineers from Greece, Israel and Cyprus. During an open group session with conference participants, accidents that take place in areas open to the public were discussed. In these cases, the general public may be exposed to dangers resulting from electro-mechanical failures in operating devices. During this group session, the disturbing fact that, even though there were increasing numbers of safety regulations for these systems, there were also increasing numbers

of accidents was discussed. I also pointed out that the numbers of fatalities from these accidents had been rising. The equipment, which should have been kept safe and operational by work performed by organizational maintenance departments, was, in fact, presenting grave safety hazards.

In further group sessions, various other conference participants mentioned that previous research studies which had not yielded a clear explanation of the cause of the problem had been empirical, based on quantitative research methodologies. It was felt that the quantitative studies must have failed to reveal some key elements. Gradually the discussions moved towards exploring the possible advantages of qualitative studies, with open ended questions which form the basis of research methods related to grounded theory (Glaser and Strauss, 1967). As the quantitative studies had failed to lead to any organizational improvements in SMEs, we agreed that a radically different approach was needed. The discussion then turned into a brain storming session, with people offering ideas for a research plan that would contribute a richer level of relevant knowledge. It was felt that qualitative methods including a provocative use of various existing theories combined with action research (as proposed for example by Lingard, Albert & Levinson (2008); Goldkuhl, Cronholm & Lind (2020) and Ramsey, (2011) could complement quantitative studies and yield a fuller picture of what was happening on the ground. It was hoped that new qualitative studies could lead to fundamental changes in work methods which in turn would lead to accident reduction.

Following this conference, I participated in a series of incident inquiries following accidents related to maintenance work. Three examples of these incidents are given below (section 1.4) to clarify how the lack of awareness and comprehension of standards is linked to many of these incidents. Following the discussions at the conference and the participation in the investigations of these incidents, my concern about the situation gradually crystalized into a determined decision, to personally investigate what was causing the rising numbers of accidents related to maintenance work in SMEs and to improve maintenance safety and reduce the incidence of accidents.

I initially approached an organization called the Israel Enterprises Organization (IEO) which later became the Israeli Business Development Organization (IBDO) usually referred to as MATI (from the Hebrew Acronym for *Mercaz le Tipuach Yazamut)* to accompany the research study into the accidents associated with maintenance work. I composed several dictates together with MATI regarding the research design. I initially agreed with MATI to

carry out a qualitative or mixed methods research study, grounded in carefully conducted field work so that the experiences of people working in maintenance in SMEs would lead to a fuller picture of what was actually taking place. Furthermore, to encourage participation of key personnel an action research approach was adopted, where managers would be involved in the research and in finding solutions to problems revealed. Combining these approaches developed into a proposal for action research, repeatedly assessing the situation on the ground and addressing issues arising through interactive coaching sessions, and returning to reassess the situation through several cycles. The initial results from interviews I conducted with maintenance personnel working with SMEs included in the study, would indicate which standards were not implemented as they were not understood, and coaching sessions looking for improved comprehension of critical issues would be followed by repeated interviews.

1.2 My personal background and rationale for undertaking the study

As my primary expertise is with maintenance departments of SMEs, and my main interest lies in accident prevention and improving the safety of those working in these departments, and of the facilities they maintain, I felt I was in a good position to carry out this study. I have been a consultant to organizational maintenance departments in SMEs over the last 30 years, having formed my own consultancy firm in 1995. The consultancy specializes in organizational maintenance improvements and problem solving.

In 2000 my firm secured consultancy bids positioning it as one of the leading consultancies in this particular field of safety engineering both locally and internationally, thus enabling the company's involvement in various international organizations, private as well as governmental. Since its creation, my company has worked in cooperative endeavours with per-project associates specializing in various engineering fields. These projects in maintenance departments of SMEs are often initiated following accidents or operational equipment failings resulting from inadequate functioning of their maintenance teams. During the last 30 years, I have seen frequent changes and modifications in the specifications and needs of maintenance departments. Whenever new technical developments bring about changes, either in the structures worked on by maintenance teams, or in equipment they use, new standards are written updating safety information, in accordance with the new developments. In order for the updated information contained in the standards to be put into practice by maintenance teams, it must appear in work guidelines. From personal experience, I was aware that, in practice, this often does not happen.

My involvement in consulting for maintenance departments in SMEs including public and governmental organizations, led me to being appointed to various public and official professional committees, as a leading engineer and chairman. This role included the responsibility for the formulation or modification of standards on the one hand, and the activities involved in enforcement of these regulations on the other hand. This involved taking action to ensure that the regulations from standard bodies are introduced to and imposed upon maintenance departments and accepted by them. This background led me to take an interest in how the failure to include information from standards in work -guidelines impacts on the rate of accidents occurring in maintenance departments. I then developed a specialization in "rephrasing" regulations and standards into executive working procedures adapted to an organization's specifics and needs.

My focus on safety was heightened following a series of accidents in Israel. These received greater public and media attention after the collapse of the floor of a wedding hall while guests were dancing, with 23 guests losing their lives and up to 250 being seriously injured (Zeiler Committee report, 2003). This event infamously became known as “the collapse of Versailles Hall in Jerusalem” which occurred in May 2001 (Zeiler Committee report, 2003). I became involved in the investigation after having been involved in three other accident investigations conducted in Europe. In all cases the primary conclusions included one correlating factor: incomprehension and improper implementation of safety standards.

1.3 The context of the study

The setting for this thesis is maintenance departments in SMEs, such as hotels, retirement homes, and healthcare facilities. These organizational maintenance departments are responsible for the safe upkeep of the premises of the organization as well as all of the equipment, furnishings and fittings within those premises. These departments are also supposed to ensure that both employees and members of the public will remain safe when visiting these premises (Kelly, 1997).

1.4 Examples illustrating the problem.

I offer three examples that demonstrate why further investigation into the problem explored in this study is required. These examples illustrate why accidents and fatalities occur even

when new standards exist which should prevent these occurrences. I was personally involved with all of these cases, and the descriptions result from personal observations. These examples also demonstrate how missing pieces of information are not necessarily discovered in quantitative studies looking into maintenance related accidents. Qualitative studies using grounded research involving interviews with personnel may yield a richer picture, including the 'missing links'. The participants guide the research process by describing the phenomena as they experience them, without being influenced by suggestions of causation brought in from the outside. Paying attention to the actual words used by the interviewees allows ensures that details are not missed.

The first case deals with outbreaks of Legionellosis, the second case deals with hydrotherapy equipment and the third deals with a fire at a holiday complex. At first sight, it may appear that there is nothing in common between these three cases. However, in all cases new standards exist that should have prevented all fatalities. In all cases, it became clear during discussions with personnel, that they were not aware of the new standards, or they were not properly understood.

This gave rise to the question of how to gain a clear picture of the familiarity of maintenance personnel with standards. How could we establish which parts of relevant standards are known and understood in each maintenance department? Furthermore, how can we discover which parts of standards are known but not understood? If maintenance personnel are not familiar with standards or don't understand them, what can be done to rectify this situation? Furthermore, is there sufficient motivation in maintenance departments to learn about standards and ensure that all personnel understand them clearly? Lastly, what methods would best suit accurately gaining the necessary information and where necessary introducing systems to improve familiarity with standards and their comprehension?

1.4.1 Legionellosis outbreaks

The first example involves outbreaks of Legionellosis, a potentially lethal disease also known as Legionnaires' disease caused by the bacteria from the *Legionella* genus (Rathmore, 2018) usually *L. pneumophila* (WHO, 2017). Legionnaire's disease is an acute respiratory infection, which may be lethal for the elderly or immunocompromised (Cunha, et al., 2016). The *L. pneumophila* bacteria naturally occur in low numbers in cool water and soil but they grow

exponentially in stagnant water at temperatures between 25°C and 45°C (ECDC, 2017). If cooling/heating towers and centralized air-conditioning systems are not properly maintained and water collects at these temperatures *L. pneumophila* outbreaks may occur with fatal results (CDC, 2017).

As Legionnaires' is a reportable disease in many countries, records of its incidence are held in Israel, the EU, the US and in other countries (CDC, 2017; ECDC, 2017). After the conditions promoting the growth of *Legionella* in water were elucidated, a European Standard giving directions on how to control and prevent the growth of *L. pneumophila* called "Approved Code of Practice and Guidance L8" or "ACOP L8" was published. Systems do exist to prevent *L. pneumophila* growing in air-conditioning units, but they are often not applied (National Academies of Science, 2020). In 2017 the American CDC and European ECDC issued on-line 'tool kits' or practical guides: Developing a Water Management Program to Reduce *Legionella* Growth and Spread in Buildings. However, outbreaks continue to happen, for example in hotels in Spain and the US (Garcia-Fulgueiras, 2003; National Academies of Science, 2020). The introduction of national regulations for legionella control in water systems has also been discussed over the last two decades Israel. After the lengthy discussions, in which I was involved, it became apparent that making appropriate changes to the law would be a lengthy process, leaving poorly maintained central air-conditioning units still in place. A conference of experts was convened and a new standard was introduced after three months, stating that control systems should be incorporated in air-conditioning units, regulating water temperatures in such a way that the *L. pneumophila* bacteria would not be able to grow. It was emphasized that water reservoirs must be maintained outside of the range conducive to the rapid growth of the *Legionella* bacteria. However, these regulations have not completely eliminated incidence of the disease. Instead, 294 cases of Legionnaires' disease were reported in Israel from 2006-2011, with a much higher proportion of nosocomial cases than that found in the EU (Moran-Gilad, et al., 2014).

This caused great consternation as the introduction of the standards did not have the desired effect. A closer look was needed to understand what was actually taking on the ground. I discovered that no updates had been sent to any operating bodies or any maintenance department governing organizations who should implement the new regulations (personal communication). The standard exists, but there is no **knowledge** of it in relevant organizations, so it is not implemented. This triggered many questions. How can we ensure that written

regulations become part of an organization's pool of knowledge and that this knowledge is put into practice on the ground? Were there failures in communications? Did someone fail to understand the standards and therefore not communicate them? Some hints were found in a tragic occurrence. Eighteen months after the standard was written a hotel guest died from Legionnaire's disease. In the investigation that followed it was found that no-one representing the hotel in question or the chain the hotel belonged to, was in any way aware of the new standard that could have saved the guest's life. If the standard had been included in easily understood language in work guidelines the problem would have been resolved. Furthermore, if assessments of professionals' knowledge of standards was included into part of routine training, the issue would have been highlighted.

1.4.2 Instillation and use of hydrotherapy equipment at health centres.

The second example relates to precautions which should be in place when installing and using electro-mechanic hydrotherapy equipment at medical facilities. I was called to investigate this case, so this a personal account.

Around the beginning of the millennium, some specialized medical centres began to offer hydrotherapy treatments either with the patient being inside the hydro-therapy pool, or just the effected limb receiving hydro-therapy under water. The therapists carrying out the treatments use electrical devices which are attached to the central electricity grid of the medical facility, constructed in ways to protect both the therapist and the patient from electrocution. Standards have been written dictating details of the preventative modifications to be used with these pieces of equipment. These standards have been revised continuously since 1995, according to technological developments, so that protective measures are included which prevent the over-heating of the electricity infrastructure supplying the power, which could lead to the outbreak of a fire.

About three years after the standard was updated in 2002, an accident occurred at a medical facility during the use of electrical devices in a hydrotherapy pool. A fire broke out as a result of the accident, causing a number of fatalities. The medical facility was evacuated and it took more than eight months for the place to be refitted. Accident investigations look at barriers, either physical, operational or technical that should be in place to protect people from harm. In this case, investigators found that the protective actions needed, which would have prevented the accident are outlined in standards for the piece of equipment in use, which had

been updated about three years earlier. These included specific precautions that must be taken to prevent overheating. The investigators discovered that no one at the medical facility knew about these updates. This again provoked questions as to why published standards that exist are not reaching the very people who are supposed to implement them, and more crucially what can be done to change this. Furthermore, in an additional investigation which my firm undertook, only one medical facility, where the devices had been developed, knew about the update in the published standards' requirements. Was this a question of broken lines of communications? Was the problem related to ignorance, lack of comprehension or lack of compliance for other reasons? When I presented the revised standards to people working in various capacities at the facilities, none of those interviewed including engineers understood the details of the revised standard, until it was explained to them using more comprehensible language. If highly trained engineers working in medical facilities could not put the information contained in the standards into practice, it seemed possible that this is a widespread problem. I begin to focus on the idea that the problem was not only ensuring that up to date standards are included in work guidelines, but also that easily understood language is used, including all information in a clear and accessible way.

1.4.3 Fire at a beach bungalow resort.

A further example from personal experience relates to an investigation into a fire in a beach bungalow resort hotel in Greece which killed an entire family. An inappropriate electrical installation had led to the fire starting during the night when the guests were asleep. A proper electrical inspection according to international standards would have revealed the problem, but no one at the hotel knew about the particular standard that could have prevented this tragedy and no one was trained to verify compliance of the system with the standards. Worse still, none of the maintenance personnel understood the necessary actions needed to avoid this type of accident in the future. Coaching sessions were needed to explain the relevant information in the specific standards. However, the wording of the standards is so complicated that the language needs simplification before the information may be understood.

Similar findings were reported from other accident investigations both in Europe and in Israel. This prompted professional unions to publish appeals for research projects to be conducted on site safety issues. It was becoming increasingly obvious that something had to be done to change the ways that maintenance departments in SMEs operated making them

more familiar with important safety standards. What was not known, was how to achieve a situation where maintenance team leaders would include safety regulations they did not understand, or were unaware of, in their daily work guidelines.

This gave rise to the question of how to gain a clear picture of the familiarity of maintenance personnel with standards. How could we establish which parts of relevant standards are known and understood in each maintenance department? Furthermore, how can we discover which parts of standards are known but not understood? If maintenance personnel are not familiar with standards or don't understand them, what can be done to rectify this situation? Furthermore, is there sufficient motivation in maintenance departments to learn about standards and ensure that all personnel understand them clearly? Lastly, what methods would best suit accurately gaining the necessary information and where necessary introducing systems to improve familiarity with standards and their comprehension?

1.5 Insider research

My personal involvement in research relating to my company's work, termed insider research, needed some consideration. Beyond the obvious advantages of conducting action research in a field that I am already heavily engaged with, attention needs to be paid to my dual role while conducting the research, as both a professional consultant and research student. The need to pay great attention to objectivity and reproducibility of the research has been addressed by many scholars in recent years (see for example, Coghlan, 2007; 2019). My precise situation was addressed by David Coghlan (2019), by Coghlan & Casey, M., (2001) and by Holian and Coghlan (2013).

1.6 Research objectives and aims

Having identified the lack of standards' implementation as a possible critical factor in accident causation, my first aim was to substantiate this by surveying accident investigation reports and create a list of standards relevant to maintenance work the implementation of which would have prevented the accidents being reviewed. The next aim was to proactively discover which of these standards were implemented by maintenance managers and team leaders. In cases where standards were not implemented, I needed to ascertain the reason for

this. Were they not aware of the standards? Were they aware of them, but not capable of following them for various reasons including being unable to comprehend the way the standards were written or unable to access the complete standard as it was scattered through various publications? My main aim was for maintenance departments to have properly organized work procedure guidelines including the critical information from the standards. To achieve this, I needed to categorize those standards that should be enforced, by the degree to which they were understood. The interviews explored which standards were only partially understood, which were misunderstood in their entirety and which were completely lacking from the personnel's and managers' cognizance when formulating work guidelines. Having witnessed the failure of initial investigations to resolve the problem, the logical step was to adopt a different strategy based on a more practical approach to problem-solving.

The overall objective of the study was to work together with maintenance professionals to rephrase crucial information from relevant standards in such a way as it became clearly understood by them. The ultimate aim of the study is for the rephrased, comprehensible information to be included in all SME maintenance department work guidelines, thus contributing to a decrease in accidents in the field.

1.7Actionable Knowledge.

The actionable knowledge of the study includes organized tables with lists of standards sections that are crucial for maintenance work. However, as discovered during the research the information needs to be provided in comprehensible language. By working with maintenance professionals, the information is being rephrased, and then in further rounds of action research will be assessed again and further adapted by the people who are meant to work with this information to ensure that it is can be properly understood by people working in maintenance.

As the rephrased information is gradually included in the work guidelines of more maintenance departments, this will become a general resource, which it is hoped, will prevent avoidable accidents and loss of life.

1.8 Summary

Safety in maintenance departments is my main field of professional interest, having formed a consultancy in 1995 specializing in organizational maintenance improvements and problem solving in the types of SMEs mentioned above. Numerous fatal accidents related to maintenance work in SMEs in Israel (Zeiler, 2003) and other places around the world (Holmgren, 2006) convinced me that there is a fundamental need for significant change in the way maintenance departments operate. Action research is considered a good technique when seeking to promote change in an organization (Argyris,1976). The bottom-up approach helps to understand processes taking place on the ground within and organization.

The principal long-term aim of the study was to eventually introduce a novel order of guideline composition and work procedures into the maintenance departments. This would fundamentally change work patterns which have been proved unsafe. The desired end result is for the information contained in relevant standards to be included in work and maintenance guidelines BEFORE the company begins to operate on a project. This is to say, safety, energy efficiency, environmental protection, accident prevention, risk assessment and mandatory maintenance work would be studied and taken into account from the very beginning of the company's formation and prior to starting operation.

Interviews with personnel indicated that the reason that information from standards was not included in work-guidelines, was that the standards are written in complex language, which the personnel did not always understand. Furthermore, it is not always clear which standard applies to which situation. The research found that when standards were rephrased and included explanations about the context, the personnel were willing to incorporate the information in their work procedures. Coaching sessions including interactions between myself as the researcher and personnel were found to be a good way to introduce and explain complex terminology included in standards. These interactive sessions also allowed me to pinpoint the information needed in explanations of standards for each maintenance department. With better understanding of the situation, researchers can work effectively with the workforce and management to overcome resistance to change (Hampshire, 2000; Montgomery et al., 2015; Tanner, 2005).

CHAPTER 2 LITERATURE REVIEW

Real time organizations do not fit easily into mathematical models – they have social and political dimensions (Mingers, 2006).

The literature review explores the main topic of this study which is accident prevention through implementation of the safety standards designed to ensure minimal risk at the workplace. The theoretical foundation to the qualitative research approach based on multi-grounded action research with a provocative use of theory is briefly introduced. The review also explores the research context which is maintenance departments in SMEs.

It became evident during my review of maintenance literature that it does not refer to the implementation of safety standards in maintenance work or to their incorporation into work guidelines. The classical issues in this literature are costs (Aldairi et al., 2015; Dhillon, 2002), work efficiency and performance indicators (De Groote, 1995; Swanson, 2001), maintenance strategies including outsourcing or in-house maintenance (Assaf et.al., 2011;Bertolini et al., 2004; Suweero, & Moungnoi, 2016) and accidents reduction (Alsyouf, 2009; Campbell & Reyes-Picknell, 2016; Kelly, 1997). The literature also lacks studies on safety (Lind, 2009) and safety issues arising from inadequate maintenance work (Holmgren, 2006). It has few (if any) descriptions of professionalism, knowledge and organizational learning regarding safety. There was an almost hermetic divide between the existence of the published safety standards on the one hand and both scholarly literature on safety and, perhaps even more crucially, maintenance work guidelines on the other. One of the fundamental attributes of Action Research is the aim to bring about change on the ground. The plan of conducting a multi-grounded action research study involved undertaking qualitative research with maintenance personnel, and encouraging their active participation in the solution, ensuring that an effective double loop learning process could take place that would reveal why the problem exists and what could be done to change it. The essence of the change needed was breaking down the barrier between published safety standards and the practice of maintenance work on the ground. The two steps towards achieving this include firstly understanding why this barrier, leading to a critical gap in knowledge amongst maintenance professionals exists, and secondly determining an effective method of organizational learning that would close the gap.

Issues of organizational learning, knowledge in practice, the differences between knowledge and knowing and the implications of provocative theory on knowing in practice are therefore crucial to the theoretical framework of this study. The study, which started with a review of the existing safety regulations published in standards, following an in-depth study of accident reports which cited long lists of safety standards that had not been implemented, the implementation of which may have prevented the accidents, placed me in a position of knowledge, which necessitated knowledge transfer during the Action Research, the very process of which also involved knowledge creation with regard to organizational learning. Being a Research Practitioner, working within organizations with whom I had professional contracts, engendered opportunities and constraints. Identifying what was known and what was being implemented in each department was an extremely sensitive task, but an essential step which later enabled tailoring coaching sessions to the precise needs of those participating. Following on from the work of Gherardi (2000) and Orlikowski (2002) on knowing in practice, I was aware of ongoing processes of learning and knowing that take place in organizations and essential role of individuals working together socially in acquiring and disseminating knowledge. The design of the interactive coaching sessions also was gradually altered in response to the efficacy of different types of learning observed during the sessions.

The chapter opens with a brief review of existing health and safety legislation and the theoretical context of health and safety theories. While the theoretical framework of Action Research *per se* is discussed in Chapter Three, in this chapter I consider the theoretical framework for Multi-Grounded Action Research as a research practitioner and I also explore theories of knowledge including ontology and epistemology; information use, knowledge boundaries and transfer and social learning and ontologies of knowledge. I will also present a review of the literature relevant to the research setting including maintenance department management and accident prevention.

The multi-grounded action research approach will be discussed further in chapter three, but having explained in the introduction that previous quantitative studies into the causation of maintenance accidents had failed to produce results the general theory will be introduced here. Up until the 1960s it was strongly felt that empirical research should be quantitative, with qualitative approaches being inadequate. The publication of the book *Awareness of Dying* by Barney Glaser and Anselm Strauss and their subsequent publications on theory grounded in carefully gathered, detailed qualitative research changed that concept (Strauss &

Corbin, 1998). In this study, my work started with a detailed reading of accident reports citing safety standards that were not cited and continued with semi-structured interviews with personnel in maintenance departments. The open-ended questions allowed each interviewee to give detailed answers to questioned asked, in their own words. I also adopted elements of coding and memoing from grounded research. The initial grounded theories were later developed into constructivist grounded theory by Charmaz (1994). In this approach, study participants co-construct data with researchers. As a consultant to the SMEs whose maintenance departments participated in the study, this was an appealing approach. It was easier to engage companies in the research when it was understood that their participants were not simply reporting events but also involved in shaping the data collected. From the beginning of the study, it was also clear that it would involve active participation of maintenance managers. Their active participation was essential to learning how explanatory material would be worded in a way that would be clearly understood, and would make a real difference on the ground.

Combining the careful qualitative investigations of constructivist grounded research with the participatory nature of action research, as suggested by Dick (2003) and by Linguard, Albert and Levinson, (2008) therefore seemed the best approach. Furthermore, action research is built in spirals of action followed by reflection and revision. It also looks for practical solutions to problems, allowing a gradual refinement of solutions until the best fit was reached for the maintenance departments. One further element, however was needed for the research methodology, with that being a theoretical framework. While traditional grounded theory relies solely on inductive reasoning from the empirical data observed in the field, without undergoing deductive reasoning using theories reached from other studies, multi-grounded theory (Goldkuhl & Cronholm, 2010) combines empirical studies with deductive use of theoretical frameworks. The combination of Multi-Grounded Action Research (MGAR) suggested by Goldkuhl, Cronholm & Lind (2020) therefore seems the best fit for a theoretical framework to this study. While action research is well formulated to create practical solutions, combining this with empirical observations collected by the researcher and adding a theoretical framework as suggested in MGAR. This combined approach also seems in keeping with my own role as a research practitioner. The theoretical element separates this research study from my work in my role as a consultant, while the participatory element found in action research acknowledges the social processes involved in learning and

enhancing the knowledge held within an organization. These topics, together with the provocative use of theory are discussed further in section 2.8.

2.1 Occupational Health and Safety (OHS): Government Legislation on OHS; Safety Theories

2.1.1 Major Health and Safety legislation in Israel

Government Legislation on Occupational Health and Safety controls activities in geographical areas under the government's jurisdiction and so varies around the world. The legislation is lengthy and complex, uses different units in different countries, and gives details relevant to the particular country to which it applies. This provides challenges for multinational corporations which must comply with local as well as international regulations, and may need to convert units and figures to those applicable in different settings. In Israel there are three main pieces of health and safety legislation: Safety at Work Regulations (Occupational Hygiene and Health of the Public and Workers with Harmful Dust), 1984 (an amendment in 2000 prevents the use of asbestos in construction); Work Safety Ordinance, 1970; and Labour Inspection Law, 1954.

2.1.2 Implementation of Health and Safety Regulations in SMEs in Israel

In Israel, Small and Medium Sized Organizations are subject to local and national Health and Safety regulations, with on-site implementation achieved through workplace guidelines. These guidelines include the names of the safety engineers and inspectors, risk assessment outlines including mention of particular hazards, lists of work requiring special permits such as work at height, work in a confined space, high voltage access and abrasive blasting. Furthermore, the guidelines should specify authorizations required for issue of permits. Safe work method statements and detailed work instructions, including names of standards to be followed should be included.

2.1.3 Health and Safety Theories

Current knowledge of theories addressing Occupational Health and Safety (OSH) from economic and psychological perspectives are discussed by Pouliakas & Theodossiou, (2010) in terms of inputs and outcomes, and implications of deficits of OSH. They cite the theoretical underpinnings of OSH as being grounded in labour economics, such as the theory of *compensating wage differentials* (CWDs), whereby workplaces with hazardous conditions offer higher salaries to compensate for the risks. It should be to the advantage of companies to minimize risk; however, the researchers point to many reasons why this is not necessarily

translated into practice. The researchers emphasize that studies in cognitive psychology indicate that employees underestimate the risks of injury at work. With CWDs not offering an adequate theoretical framework, other studies have focussed on "willingness to pay" (WTP) for valuing risk of accidents at work. WTP attempts to estimate the extent to which an employee is willing to take less salary in exchange for additional safety. However, none of these economic theories have succeeded in reducing workplace accidents in general, or those related to maintenance in particular.

In order for any public policy to be effective there must be quantifiable indicators of safety at work. Organizations including the WHO, ILO and EU have identified indices of OSH, including expenditure on OSH; efforts made to comply with OSH regulations; and the investment in OSH prevention activities. The World Health Organization (WHO), International Labour Organization (ILO) and European Commission all issue statistics on time lost due to work accidents, expenditure through sick pay and other expenses due to accidents, relating to inadequate investment in improving health and safety regulations at the workplace. Theoretically, knowledge relating to work-related hazards and risks should help limit the cost in terms of human health and economic losses. However, as will be discussed below, it is imperative for this knowledge to reach key stakeholders in organizational maintenance departments, and put into practice for it to impact on accidents.

Three theories of risk and safety are discussed by Cooke, (2009) who also highlights the gap between theory and reality, or 'reality and rhetoric'. Giving a historical context, Cooke first briefly reviews the manmade disasters of the 1970s, such as the Three Mile Island nuclear catastrophe that led to increased attention to risk, citing Beck's work "Risk Society" (1992) as claiming that 'destructive forces of modernization' are becoming irreversible and that a deep distrust in expert systems of risk management. Beck claims that risk in society is determined by an unelected elite of technocratic experts working in "irresponsible bureaucracies". Cooke points out that Beck's work exemplifies a 'decline in deference' towards experts (Durant, 1998) within which contemporary approaches to risk and safety have developed. Attempts to reverse this 'decline in deference' to experts may involve narrowing the gap between research scholars and practitioners, with professionals from the field involved in practitioner research, sharing the vocabulary and experience of the workforce they are hoping to involve in improved workplace enforcement of safety regulations.

Safety theories acknowledge that organizational structures may lead to a higher incidence of accidents. Cooke (2009) discusses Normal Accident Theory which was followed by High Reliability Theory and Cultural Theory. Normal Accident Theory, developed by Charles Perrow (1984), suggests that accidents occur under conditions of organizational complexity where flexibility is lacking in organizational procedures. Such conditions may be resultant from attempts at cost savings. However, accidents may also be caused by management failings as well as by systems failures. While accidents may be caused by component failures, that also relates to inadequate maintenance and inspections designed to avoid such failures (see sections 2.2.6 maintenance strategies).

High reliability theory aims at promoting learning organizations (see also section 2.6.2) and has been linked to the promotion of safety culture, with Cooke (2009) quoting the Advisory Committee on the Safety of Nuclear Installations' definition: The safety culture of an organisation is the product of individual and group values, attitudes, perceptions, competencies and patterns of behaviour that determine the commitment to, and the style and proficiency of, an organisation's safety management (Health and Safety Executive 1999). However, safety culture still needs to be based on the implementation of accessible knowledge and effective methods of ensuring that directives followed are up to date and applicable to all aspects of the situation within which they are applied.

Other accident theories take an anthropological approach to risk. This approach is adopted by cultural theorists who assess groups or organizations according to their degree of social cohesion, with cultural biases affecting risk perception. While higher degrees of social cohesion may lead to better communications and more uniform behaviour, it may also lead to more negative behaviour patterns being widely adhered to. For example, in Israel, there is a well-known cultural ethos which promotes the disregard of safety regulations and is related to a general world view of 'relying (blindly) on each other' and presuming that things will work out fine in the end, (Rabin, 1992) which adds to the problems faced when attempting to reinforce implementation of safety regulations. Indeed, Cooke (2009) states that much recent commentary on risk and safety has focussed on the dysfunctions of professional tribalism and the need to replace a culture of professional secrecy with a culture of openness (Bristol Royal Infirmary Inquiry 2001).

Guerin and Sleet, (2020) suggest that methods from social and behavioural theories are important in the implementation of prevention of workplace accidents. In particular,

behavioural change theories such as the Health Belief Model (Rosenstock, 1974) may be useful for testing the effectiveness of interventions. Active (behavioural) theories assume people may be able to take some kind of action to prevent accidents and promote their own health, while passive (structural) theories relate to changes in the work environment. There is ample literature on employee characteristics related to decision making and cost benefit models, value expectancy models, health belief models and theories of reasoned action. While they are of limited value to this study, it is worth noting that where employees have strong beliefs in self-efficacy and response efficacy, they may be more likely to take preventative actions and to follow safety regulations. Following on from these ideas, behavioural change models such as the Transtheoretical Model (Prochaska and DiClemente, 1982) may be of interest if they are effective in bringing about behavioural changes leading to better workplace practice regarding safety. Dejoy (1996) integrated these safety theories into a model of workplace self-protective behaviour based on hazard appraisal, decision making, initiating action and adherence.

In view of the statistics released by the ILO presented above, it appears that despite the literature reviewed here on safety theories, they are not yet yielding hoped for results in practice. The divide between knowledge and practice and attempts to overcome it will be discussed further below (see section 2.5). Theories and practice of safety and accident prevention in maintenance departments in SMEs are further discussed in section 2.4. However, the emphasis of this study is on how knowledge is transmitted within maintenance organizations so that it is effectively translated into safe practice.

2.2 The Research Setting: Organizational Maintenance Departments

2.2.1 Definitions of key terms and concepts of Maintenance

Before continuing to discuss literature related to the research, it is necessary to define some of the terms central to this study. The term ‘maintenance’ may be defined in various ways according to context. In the most general sense, the Oxford dictionary defines ‘to maintain’ as to “cause something to continue” or “to keep something in existence”. Maintenance has been defined as the process of maintaining an item in an operational state by either preventing a transition to a failed state or by restoring it to an operational state following failure (British Standard BS3811:1993; Misra, 2008). Maintenance can also be defined as including all activities necessary to retain the functions of items during their life cycle or to restore items to the state in which they can perform their proper function (EN 13306:2001;

Manzini et al., 2010). When considering buildings, maintenance is defined as the execution of activities which keep, restore or improve every part of a building, its services and surrounds, to a currently acceptable standard, and to sustain the utility and value of the building (Ghazi, 2016; Seeley,1985; Moubray, 1997).

In this study, the maintenance work discussed is conducted by maintenance departments of SMEs, such as hotels, retirement homes, and healthcare facilities. In this context, the maintenance work also relates to activities that minimize or prevent the possibility of reduced performance of machines or equipment due to corrosion, contamination, or deterioration due to wear and tear (Swanson, 2001). Properly regulated maintenance not only ensures optimal functions of electrical and plumbing systems, the continued functioning of the facility, and also contributes to the financial well-being of an organization (Marquez, 2007). In other words, in organizations, the quality of maintenance work has a dynamic relationship with the performance of the organization, with maintenance failures impacting directly on the performance of organizations (Kelly, 1997).

2.2.2 Maintenance Departments

The multi-grounded action research described in this study, seeks to introduce changes and improvements in safety issues within maintenance departments of SMEs. These departments are supposed to ensure that standards of service are met, within a safe environment (Kelly, 1997). Maintenance departments are also responsible for all of the operations necessary to keep the organization functioning at full performance levels (Kelly, 1997; Swanson, 2001; Galar et al., 2017). This includes ensuring that all structural, functional and aesthetic aspects of buildings, including plumbing, mechanical and electrical fittings, water heating and cooling systems, are in good order; ensuring that all equipment is functioning optimally, in energy efficient ways; that all furnishings and fittings are intact and safely installed together with any managerial and administrative activities necessary (Kelly, 1997; Gassner, 2009; Ghazi, 2016; Misra, 2008).

Maintenance departments perform scheduled tasks designed to prevent equipment failure prior to the end of its life expectancy. They also repair damaged equipment and replace outdated or old equipment (Chan, et al., 2003; Ghazi, 2006; Seely, 1985). The resources available to maintenance departments needs to be planned to allow for corrective

maintenance when required (in some cases following inspections) (Gassner, 2009). Proper organization and planning of scheduled maintenance allow the best possible preparations, including the selection of the most suitable equipment and techniques and ensuring sufficient resources are available for personnel, materials and equipment (Kelly, 1997; Levitt, 2000). This also allows time for proper training of personnel for site and job specific tasks when necessary. Investing resources in properly planned scheduled maintenance may therefore be key to the quality of work necessary to prevent accidents resulting from unplanned and poorly carried out work.

With increasing automation, numbers of personnel employed in production has decreased, while the relative proportion of capital invested in infrastructure, technology and machinery has increased. Machine maintenance therefore plays an increasingly crucial role, with maintenance costs forming an increasingly significant part of organizational spending (Garg & Desmukh, 2006). However, the importance of maintenance departments within an organization has not always been fully appreciated, resulting in under-funding of these departments (Galar et al, 2017; Marquez, 2007). In recent years well organized maintenance departments have developed from being a loosely cohesive group of employees into a structured, hierarchical department in the organization (Bonde, & Fulzele, 2013; Campbell & Reyes-Picknell, 2015; Carnero & Gonzalez-Prida, 2017; Cigolini et al., 2008). The large departments in turn created a demand for more complex administration and managerial structures within the department. As the size and complexity of the departments grows, the importance of effective communication of crucial safety knowledge also rises. The quality of maintenance work is affected not only by the technical work performed by maintenance crews, but also by the communications within the department between management and teams (Holmgren,2005; 2006; Lind, 2009: Reason, 1997). However, it is again important to emphasize that solutions to problems of communications may be in place in large concerns but not in SMEs, which typically lag behind the larger organizations with more accessible resources.

Shohet & Lavy (2004, p. 211) related maintenance to cost efficient performance defining maintenance as “ensuring the continuous, cost-effective fitness for the use of buildings at a specified performance level”. However, from personal experience I have observed that the emphasis on costs may detract from the quality of maintenance, incurring more costs later on if systems fail. A perspective of preventative maintenance is essential to avoid these costs. Indeed, the European Standard, EN 13306 defines maintenance as “combination of all

technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function (CEN, 2010). The standard implies that preventative maintenance is different to corrective maintenance (CEN, 2010; Gassner, 2009; Marquez, 2007).

The development of large, labour intense maintenance departments in large organizations, which were divided into teams with personnel with different skills and levels of professional training, including an administrative and management hierarchy, contributed to an increase in departmental costs. In order to optimize efficacy and reduce costs, organizations began to search for factors which could improve and streamline departmental operations. However, the emphasis still remained on cost efficiency rather than quality, which may have contributed to the safety problems experienced increasingly from the start of the millennium.

The diverse manpower working withing maintenance departments, all have to follow specific work-guidelines for each job undertaken. The phrasing and content of these guidelines is critical for jobs to be undertaken safely, efficiently and successfully. As will be seen below, whatever management styles and strategy adopted for implementing ongoing maintenance tasks, the bottom line remains that the quality of work performed is dependent on the maintenance professionals, their training, and their ability to follow instructions in work guidelines.

2.2.3 Professional Guidelines in Maintenance Departments.

In well run maintenance departments, work guidelines are issued covering general information necessary to maintenance teams, as well as detailed instructions for each job. The guidelines list those jobs which require special permits, such as working at heights or with electrical instillations at high voltage. Permits are only granted to ‘competent’ personnel with relevant qualifications, training and experience. Large concerns such as hospitals, port authorities, and complex production plants hold well organized guidelines for maintenance work, with a good example found in Port Hedland Port Authority (PHPA, 2020). These guidelines state that in order to hold a permit to conduct tasks, competent people must receive permits from supervisors, with these permits only issued in accordance with safety management systems, with competence being defined by Occupational Safety and Health Regulations, 1996. The work guidelines also include safe work method statements, risk assessments, forms for job hazard analysis and detailed work instructions.

Maintenance guidelines in hospitality industries, cover good practice for every part of the industry, from fitting wheels or castors to machines for better mobility, locked cages round machinery that is potentially hazardous, training required for new staff when using knives, handling heavy equipment, avoiding burns, avoiding slips and falls, to specifications for firefighting equipment and for maintaining hot and cold water at particular temperatures to avoid contamination with pathogens (HSA, 2020). In my consultancy work and while conducting this research I found that work guidelines in many maintenance departments in SMEs in Israel did not refer to crucial safety information contained in standards. The working hypothesis associates this lacuna with the high incidence of accidents related to work carried out by maintenance departments. Throughout the thesis examples are given where lives were lost when work was completed without adequate and up to date work guidelines before projects were started. The aim of the work is to change this situation so that it becomes standard working practice for all maintenance departments to ensure that all work guidelines include essential information from standards in a comprehensible format, and that these guidelines are available before the start of any new project and that studying and implementing of these guidelines is obligatory as a first step in each and every task.

When considering the problem of why safety standards are not implemented and accidents are rising, it is important to remember the vast changes that have occurred over the last 50 years in these departments. Some decades ago, a good worker in an organizational maintenance department could fulfil nearly all tasks required, involving plumbing and electrical repairs and other tasks required for keeping the organization running properly, with some basic tools. More recently, equipment and infrastructures have become more sophisticated and sensitive, involving complex computerized technologies, requiring greater levels of professionalism and specific equipment to accomplish the maintenance tasks (Carnero & Gonzalez-Prida, 2017; Cigolini et al., 2008). As equipment became more sophisticated, the standards and safety rules guiding their use became more sophisticated too.

Ideally, all safety information is communicated to relevant team members through guidelines. However, in practice, there may be a breakdown in communications somewhere along the hierarchy of roles within a maintenance department. The maintenance department manager, responsible for major decision making in connection with the organization management, is the top level of management. However, he will not be directly in contact with those carrying

out maintenance tasks. The next level of management may include inspectors, supervisors and schedulers of various maintenance teams such as electrical, mechanical and engineering teams. The tradesmen form the lowest level of the pyramid of the department administrative structure (Kelly, 1997). The guidelines that reach the tradesmen should include the necessary safety information in such a way that it is understood by the them. This ideally is assessed by middle tiers of management, who should also maintain filing systems with good work records and perform quality control (APO-ILO, 1977). In the literature quality control is reported to monitor maintenance productivity, effectiveness and organizational efficiency, rather than actual quality and safety of the maintenance work (Campbell, & Reyes-Picknell, 2015; Kelly, 1997).

2.2.4 Organization of Maintenance Departments in Small to Medium Sized Enterprises (SMEs).

Despite the descriptions of sophisticated, well organized maintenance departments appearing in the literature, from my personal experience, the actual situation on the ground, in SMEs, does not reflect the ideal state of affairs. Many of the elements including inspections, monitoring, and adequate supervision may often be lacking. This extensive incongruence between the theoretical and the practical is at the heart of this research study.

In Israel as well as in many other countries maintenance departments in SMEs face significant organizational challenges, with organizational cultures placing insufficient emphasis on maintenance (Alsheri et al., 2015; Assaf, et al., 2011; Zakiyudin, et al., 2014). There is an urgent need for more maintenance departments to employ maintenance concepts such as Reliability Centred Maintenance (RCM) and Total Productive Maintenance (TPM) (Alsyouf, 2009; Sifonte & Reyes-Picknell, 2017; Valerio & Nunes, 2017). In Malaysia, for example, the government attempted to increase the budget for the maintenance of public buildings in 1991, and again up until 2012, yet found that accidents persisted due to poor management, malpractice and negligence (Zakiyudin, et al., 2014). Various studies report that the performance of maintenance departments in SMEs is impacted upon by poor communications, insufficient availability of skilled workers, insufficient resources including a lack of specialized tools and materials as well as inadequate finance (Pitt et al, 2016; Zakiyudin, et al., 2014).

2.2.5 Maintenance Management

When conducting action research into any aspect of maintenance work, it is important to be cognizant of the scale of the impact of maintenance management systems, and of the

dynamics within which maintenance management operates. Maintenance management aims to reduce the loss of resources by conducting risk assessments and risk-based inspections. Maintenance management systems organize resource allocation required to accomplish maintenance goals, aiming to make optimum use of limited resources (Emovon et al., 2016; Galar et al., 2017). When maintenance is not carried out in an effective and timely fashion, valuable resources may be wasted. For example, it was reported that in America $3.2 billion dollars are lost on energy spending annually due to ineffective maintenance of compressed air systems (Vavra, 2007).

While multi-grounded action research typically engages with theoretical material and personnel at different levels, any change the findings may promote will inevitably have to fit in with whatever management system is operated. Maintenance management is defined in the NP EN 13306 standards:2001 as all management activities that determine the objectives, the strategy and the responsibilities relating to maintenance and their implementation through planning, control and supervision, while finding improvements including for economic aspects (Galar et al, 2017; Santos, 2017; Marquez, 2007).

A wide range of international standards from Europe (EN) and from the United States (ANSI) attempt to regulate maintenance processes and management (Galar et al., 2017). Maintenance standards include: ISO 55000 series; BS EN 13306:2007 (CEN, 2001) which outlines basic maintenance terminology; BS EN 15341:2009 (CEN, 2007) which explains maintenance indicators and BS EN 13460:2009 (CEN, 2001) which specifies documentation necessary for maintenance management.

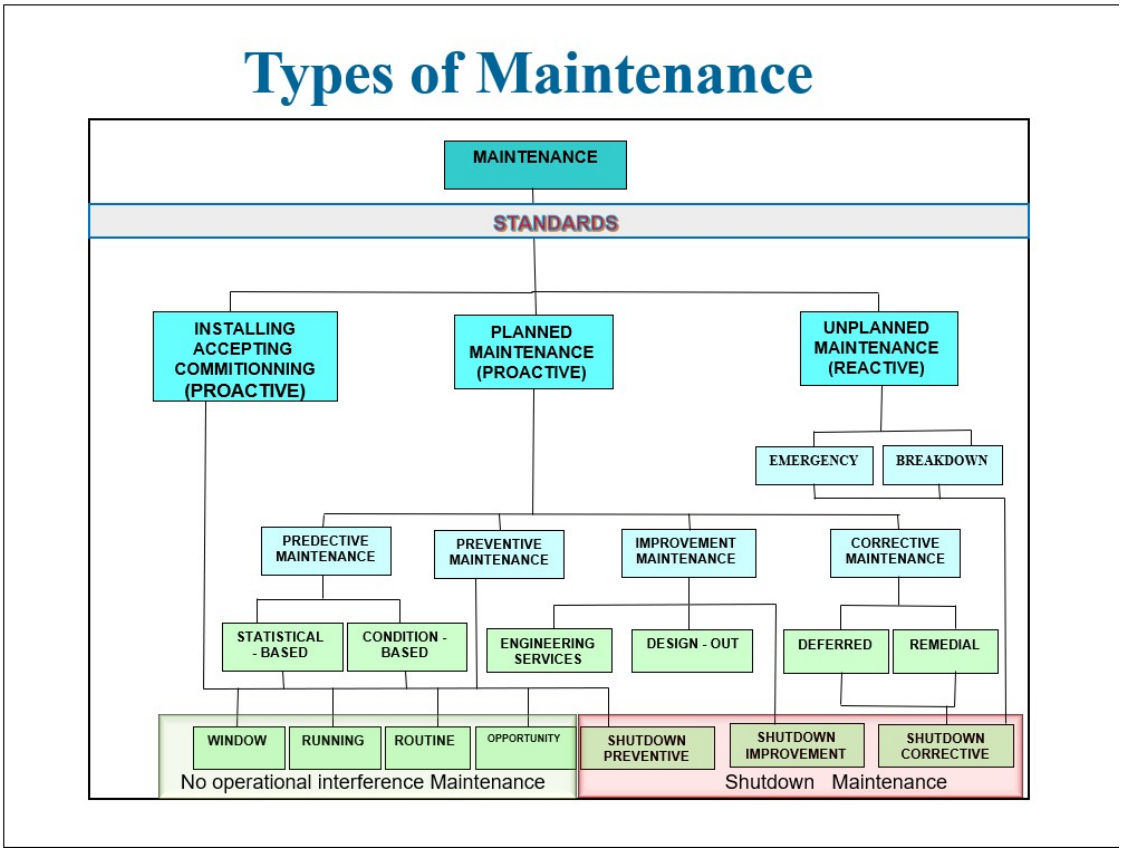
2.2.6 Maintenance strategies

Selecting the appropriate maintenance strategy is considered one of the most important decisions for maintenance management (Stanojevic et al., 2000). The selection involves considering manpower utilization, cost and budget constraints, safety factors, environmental factors and mean time between failure (MTBF) for each piece of equipment (Bertolini & Bevilacqua, 2006).

Broadly speaking, maintenance activities can be organized in line with three different strategies (see figure 2.1). Firstly, reactive or corrective maintenance which includes emergency, unplanned maintenance work following accidents or breakdowns (the work may be deferred to prevent interfering with the production process), which was the only

maintenance strategy used up until the 1950s (Gassner, 2009; Kelly, 1997). When systems were mainly based on hydraulic components, they were often allowed to run until they broke down. When electromechanical computer-controlled equipment became dominant, unplanned, reactive maintenance became less suitable (Borris, 2006). Reactive maintenance is still used in emergencies, when outsourced specialized services are often called in (see section 2.3).

Figure 2.1 Different Types of Maintenance Strategies



2.2.7 Reactive, proactive and involved proactive maintenance strategies

Secondly, there are proactive strategies which include preventative and predictive maintenance strategies. When following preventative strategies, work is organized according to a planned schedule, decided well in advance, with the jobs undertaken at set intervals (Jardine, et al., 2006; Garrido, 2009). Predictive maintenance strategies require highly skilled personnel, who can monitor systems which may be deteriorating, diagnosing faults and forecasting failures. They must be familiar with the fine details of manufacturers' instructions

for maintenance work, and with up-to-date standards for each piece of equipment (Goyal & Maheshwari, 2012; Yousefli et al, 2017). Predictive maintenance strategies are adopted by organizations for whom it is critical to maintain an incidence rate of zero equipment breakdowns. Proactive preventative and predictive maintenance strategies are combined into Reliability Centred Maintenance (RCM), and Improvement Maintenance work (Gassner, 2009; Swanson, 2001). Improvement maintenance, also referred to as commissioning maintenance, goes beyond diagnosing faults and pre-empting possible problems, by updating systems before any indications of problems are detected. With increased global competition, there has also been increased focus on the safety and reliability of all products and facilities (Borris, 2006).

Thirdly, involved proactive maintenance is a systems-based approach, focussing more on operations than on maintenance, again typifying larger organizations. The maintenance team is involved with systems from the outset, being included in the commissioning and installing processes. 'Commissioning' involves comprehensive performance tests of the equipment, logging and reporting tests and performance data, and filing design specifications (Harker, 1998). Maintenance workers involved in commissioning, having access to documentation and in-depth knowledge of the systems, will have a better capability of predicting their maintenance requirements in the future (Harker, 1998). Retro-commissioning on systems which did not previously undergo the process, identifies inadequate systems, indicating where replacements are needed ahead of time (Katipamula, et.al., 2017). Well-developed maintenance departments use data from commissioning and retro-commissioning, together with analysis techniques, to identify potential causes of failures, and can then design specifications, purchase equipment, and install operating systems to reduce the incidence of failures (Darling, 2011).

Effective maintenance management involves selecting the most appropriate maintenance strategy to make best use of limited resources (Bertolini & Bevilacqua, 2006; Emovan et al, 2017; Galar, et al., 2017; Marquez, 2007). Ultimately a good maintenance strategy may reach a type of production and service management regarded as asset integrity management which forms part of the total performance management which links economic factors in with maintenance strategies.

2.2.8 Total Productive Maintenance and Reliability Centred Maintenance

Sophisticated maintenance strategies have been developed, derived from a synthesis of approaches to maintenance work management, including Reliability Centred Maintenance

(RCM) and Total Productive Maintenance (TPM) both of which include concepts of quality and performance (Borris, 2006; Gassner, 2009; Galan &Gomez, 2018; Galar et al., 2017). RCM has been defined as "a process used to determine what must be done to ensure that any physical asset continues to function in order to fulfil its intended functions in its present operating context." (Moubray, 1997). RCM was initially developed in the aviation industry in America and asks a series of questions: what are the desired performance standards; what may cause functional failures and what may the effects of these failures be; what can be done to predict and prevent these failures? (Darling, 2011). The international Society for Automotive Engineers, (SAE), the organization developing and publishing standards for professionals in a variety of industries, wrote a series of standards for reliability centred maintenance work: SAE JA 1011 standard from 1999 and the SAE JA 1012 standard written in 2002, which include recommended practices, but are not legal regulations and cannot be enforced by law.

By contrast, TPM also started in America, but only fully emerged in Japan, where industries were expected to function at maximum capacity with no unscheduled stops (Borris, 2006; Gassner, 2009; Valerio & Nunes, 2017). TPM was aimed to allow plants and facilities to function with zero breakdowns, zero downtime, zero failures, and no loss of efficiency or production capacity (Borris, 2006). Total productive maintenance - TPM focusses on fixing every part that may go wrong, without considering costs. Reliability centred maintenance on the other hand, prioritizes work according to safety in a limited budget (Borris, 2006). TPM was initially called 'Preventative maintenance' (PM) and has a strong focus on health and safety, targeting zero accidents. Both RCM and TPM represent ideals for maintenance strategies.

2.2.9 Total Productive Maintenance as part of Total Quality Management (TQM) and Total Performance Management (TPeM)

In total productive maintenance (TPM), maintenance is regarded as part of the organization's long-term profitability, and part of a Total Performance approach (De Groote, 1995). TPM may also be considered a holistic approach that strives to achieve perfect performance while emphasizing proactive and preventative maintenance (Agustiady and Cudney, 2018). Oosterloo (2010).

The departments are governed by procedural documents, including many concepts similar to those described as relating to Total Quality Management (Willmot, 1994). The concept of Total Quality Management (TQM), is defined by the International Organization for Standardization (ISO) as "a management approach for an organization, centred on quality, based on the participation of all of its members, and aiming at long term success through customer satisfaction'. TQM according to Pekar (1995) places an emphasis on achieving quality throughout an organization, through a commitment to continuous improvement through quality standards, benchmarking and lean management (Arikkok, 2017). Many companies have adopted TQM in an attempt to improve profits, market share and profitability (Kumar et al., 2016). According to Oakland, (2003) quality may mean excellence, and is used in business to mean meeting customer requirements. The onus of excellent leadership falls on all levels of management (Pekar, 1995).

TPM is frequently implemented as part of TQM through lean management and six sigma management approaches (Al-Refae & Hanayneh, 2014; Seow & Liu, 2006). Lean management concepts aim at eliminating waste and inefficient procedures from maintenance processing, while six sigma management aims towards adopting continual improvements (sigma being the upper-case symbol of the Greek letter $\sum$ used to indicate 'the sum of'). This approach has proven particularly useful to SMEs (Seow & Liu, 2006). One aspect of maintenance work which has been shown to be improved through six sigma concepts, is the handling of maintenance records (de Souza, et al., 2014). Hybrid Lean and Sigma Six Maintenance strategies are also employed in green (sustainable) organizations, implemented through Knowledge Based Systems allowing an analytical approach (Aldairi et al., 2015).

In considering all of the maintenance strategies presented it is important to note in relation to this study, that none of these maintenance strategies focus on improved professionalism through implementation of safety standards.

2.2.10 Summary of section 2.2

We have seen that although theories of good maintenance management strategies abound, including preventive maintenance, predictive maintenance, RCM and TPM, the situation on the ground in maintenance departments of SMEs may not be ideal. In order to assess what is actually happening on the ground in maintenance departments, bottom-up action research is needed. This may pinpoint problems and allow action research work together with the personnel to introduce changes that will improve safety and environmental factors within these departments. As will be seen in this study, my background including long standing

relationships with SMEs, as a consultant for their maintenance organizations, provided the introduction into these departments, so that the research could reflect the situation from the perspective of the personnel working in the maintenance departments

2.3 Outsourcing

2.3.1 Outsourcing of maintenance work

My work with the maintenance departments included in the study, has also led to a familiarity with the reasons behind the rapid development of outsourcing in these SMEs. Outsourcing had become unavoidable component of these departments, and the existence of this phenomenon could not be ignored when considering both the methods used and the results of the studies. The reasons for the growth of outsourcing are well described in various papers (Al-Mutairi & Al-Hammad, 2015; Assaf et.al., 2011; Bertolini et al., 2004; Dude & Zitkiene, 2019; Hamidi et al., 2014; Suweero, & Moungnoi, 2016). The concept of outsourcing had initially been adopted by maintenance departments as a way to make financial savings, but developed into a perceived panacea for all management issues (Dude & Zitkiene, 2019). What resulted, (as discussed in section 2.5) however, was a rising complexity of communications and a lack of overall supervision of quality and professionalism (Al-Mutairi, & Al-Hammad, 2015; Jackson, et al., 2001).

Evolving, large maintenance departments quickly became organizational “stumbling blocks” as they became more and more expensive with lower and lower returns, pushing the organizations to search for different solutions. One way to cope with these developments was for SME maintenance departments, with less resources than maintenance departments of large international corporations, is to outsource specific challenging tasks to professional outsourcing service providers (Suweero & Moungnoi, 2016). Outsourcing, which was already quite developed in some departments, within some specific professions, such as accounting and legal services, started to be implemented in specific tasks in maintenance departments (Suweero & Moungnoi, 2016). Furthermore, with the ongoing development of ever more sophisticated technologies, maintenance workers are faced with increasingly difficult challenges, requiring greater levels of professionalism (Carnero & Gonzalez-Prida, 2017; Cigolini et al., 2008).

In practice, outsourcing leads to complexities in chains of management and supervision. While maintenance strategies are aimed at enabling organizations to function continuously, outsourced work, which was not properly supervised by inhouse management, and was lacking professionality, often caused unnecessary work disruptions. Finally, this prevented the organization from gaining any potential savings resulting from using outsourcing (Jackson et al., 2001).

The possibility of receiving high quality work at lower cost is often an overriding decision, as reported from a study in Hong Kong (Yik & Lai 2005). Similar conclusions were reached in a study of the hotel industry in Bangkok, Thailand. Out of 56 factors thought to impact on the decision whether to outsource hospital maintenance services, the quality of the work was considered the most significant, with economic factors also playing an important role (Suweero & Moungnoi, 2016).

2.3.2 Relations between Organizations and Outsourcing Bodies

One key to effective outsourcing of maintenance work, is good communications between the organization and the service provider, including proper descriptions of the task needed, including required performance levels and benchmarks. However, in many organizations outsourcing was considered as a miraculous process, increasing efficiency and reducing costs, and due care was not taken with analysing and communicating the maintenance needs of the organization. This led to a global adoption of the outsourcing concept, with decisions and their practical applications being completely detached from professional maintenance considerations (Jiang & Qureshi, 2006: Pintelon & Puyvelda, 2006). The managerial decisions were based mostly on ignorance, and a lack of comprehension of real maintenance needs and effective maintenance strategies (Jackson et al., 2001).

One reason behind the tendency to outsource maintenance work, without thinking through the decision, has been that maintenance was always considered as a “necessary and unavoidable evil” (Dhal, 2016, p. 2). Maintenance was not thought of as being of an integral part of the organization, making positive contributions to output and effective running of the organization. More and more maintenance services were offloaded onto outsourcing bodies as part of the concept of cost reduction. This took maintenance work outside the audit

procedures of the organization, and left the onus of finding skilled manpower to the outsourced service providing bodies. Poor communications between workers directly employed within the organization, and those supplied through outsourcing companies resulted in inadequate supervision and poor safety practices. As shown in Jackson, Iloranta, and McKenzie (2001, p.3) this endangered the people working in the organizations.

The outsourcing body supply a team with inappropriate skills leading to poor performance, with this leading to a lack of satisfaction from the service obtained. Gómez, et al., (2009, p.3) list the descriptive parameters needed in order to avoid dissatisfaction from outsourced services, which may result from the lack of proper initial formulation. They also suggest how to adapt the description of the outsourced requirements to the maintenance strategies: corrective, preventive and predictive maintenance, as each strategy has specific needs, and essentially how to include those parameters as descriptors in the primary agreements with in order to help gain the expected results from the outsourced body.

2.4 Safety, Hazards, Risk Assessment and Accident Prevention in Maintenance Departments

2.4.1 Safety research in SME maintenance departments

At the outset of this study I found, in agreement with Hon et al, (2010) that although there is ample safety research in the construction industry (e.g. Abdelhamid & Everett, 2000; Brace et al. 2009) and for large scale production plants (Leplat & Rasmussen, 1984) there is very little literature on safety in the organizational maintenance sector, or in what Hon et al., termed Repair, Maintenance, Alteration and Addition (RMAA). When using the combination of key words “standards” “accidents” and “maintenance” I found no papers which offered relevant solutions applicable to maintenance departments in SMEs. No studies at all were found on the prevention of accidents caused by inadequate implementation of safety standards in maintenance work conducted in organizations such as shopping malls, healthcare facilities and hotels. The literature on safety issues and accident prevention in other industries, does include prevention of accidents during maintenance work undertaken in industrial plants (Leplat & Rasmussen, 1984). This literature also refers to safety standards and the importance of their implementation (Kjellen & Albrechtsen, 2017).

Following my experience of working with maintenance departments, I think it is fair to say that the relationship between safety of maintenance work and that of the place being maintained may be summarized as follows: some accidents may result from maintenance failures, in that equipment or structures became dangerous through being inadequately maintained; other accidents occur during the maintenance activities themselves, for example falling from height, and electrocution. However, despite the two-way relationship between safety and maintenance work, the area of accident prevention in maintenance work or as a result of maintenance work has still received little research attention (Okoh & Haugen, 2014; Holmgren, 2005; 2006). Although well performed maintenance work improves the safety of buildings and organizational facilities, inadequate or incorrectly performed maintenance work may be a serious source of danger, contributing to both minor incidents and serious fatal accidents (Holmgren, 2005; 2006; Lind, 2009; Reason, 1997; Reason & Hobbs, 2003).

Reasons for inadequate maintenance work may include attitudes of workers and communications problems. For example, a case study by Mwanza & Mbohwa (2017), explored maintenance workers attitudes to safety in a mining company in Africa. They found that as in other maintenance situations, although some workers may be aware of safety issues, miscommunications led to a lack of knowledge about some critical safety issues. This highlights the importance of organizational knowledge and organizational learning discussed in section 2.6. In the current example, workers reported that accidents had resulted from incorrect use of equipment and other devices as they had not received up to date instructions. Indeed, in their study, unsafe working habits were found to have the highest rating on the Likert scale for accident causation. Furthermore, about one fifth of those answering questionnaires indicated that safety meetings were only conducted on a monthly basis in the maintenance departments, that safety rules and regulations were either never revised or only revised occasionally. The researchers recommended more maintenance safety training, defined maintenance procedures, daily maintenance safety meetings and identification of maintenance safety problems.

A disturbing finding, that many equipment failures occur shortly after maintenance work was performed (Reason and Hobbs, 2003) indicates that there may be a serious problem with professional standards of maintenance work performed. Without adequate training, supervision and precise up to date guidelines, critical errors may be made, leading to potential hazards. This was illustrated by Reason (1997) who gave an example of the numerous ways a system could be wrongly reassembled after maintenance work. A study by Okoh & Haugen,

(2013) also revealed how maintenance work could be a cause of major accidents, something that had been ignored in accident investigations.

2.4.2 Hazards and Risk Assessment in Maintenance

According to ISO 1421, a hazard is a potential source of harm. Hazards may be an inherent part of a system, or may be something that appears unexpectedly when mistakes are made under particular conditions (Lind, 2009). Studies have been undertaken identifying hazards in maintenance (Holmgren, 2006) but this is only the first step towards improving safety. The next step involves predicting future hazards and accidents they may cause (Lind, 2009). One method of predicting future hazards is through studying accident reports (Jacinto & Aspinwall, 2003; Salguerro-Caparros et al, 2015; Tuominen & Saari, 1982).

The risk level for maintenance tasks carried out by maintenance departments is decided according to scales determined by professionals. In the UK for example, the Health and Safety Executive (HSE) identifies key steps in risk assessment (Russ, 2010). Russ highlights problems relating to gaps between theory and practice. The risk assessments have to encompass all possible conditions on the ground (such as harsh weather), any other activities taking place in the surrounding areas which may impact on the project and ensure that all equipment is properly maintained. Risk assessments based on tabulated information about hazards and risk assessment standards should be part of daily work procedures in maintenance departments, and are implemented in large organizations. However, in SMEs the implementation may be lax.

2.4.3 Risk assessment Standards relevant to maintenance departments

Risk assessment standards are sub-divided according to different categories, but the first subdivision separates dangers to the environment from dangers to people. The next classification relates to the cause of the risk. Further classification is continued according to the preventive measures required to protect the environment, and the people in it, from the possible consequences of those dangers. All of these definitions of risk assessment have been supplemented by two requirements in recent years: first, to protect those around the systems, whether they are using them or just passing through them, and secondly to respect the principles of environmental protection.

According to risk assessment Standards, a risk analysis is constructed using a flowchart built from questionnaires. When the answer is given, the survey respondent is sent to the next question, and so forth. In most organizations, the flow charts are built from knowledge accumulated internally, and they only include the requirements dictated by standards at a later stage. However, these flow charts were intended to start with questions about standards' regulations and not only to end with them. The standards include exact directions on how to conduct the risk surveys, to ensure that all sections of the standards are taken into account. If the surveys don't start with regulations from the standards, the whole survey may become irrelevant.

2.4.4 Maintenance: a high-risk activity intended to reduce risks and prevent accidents

While maintenance operations are intended to prevent accidents, improve safety and efficiency; they are often high-risk activities in themselves (Holmgren,2005; HSAie, 2020 Reason, 1997). Physical risks include exposure to heat, cold, noise, vibration and radiation; biological risks include exposure to viruses, bacteria and fungi; and chemical risks include exposure to asbestos, toxic fumes, solvents and acids (AFIM, 2004; Grusenmeyer, 2002). However, it is important to note that in general, while high levels of automation reduce the opportunity for human error which may lead to accidents, in maintenance the situation is reversed. As machines and equipment become increasingly sophisticated, the maintenance worker may be exposed to increased risks during such activities as disassembling and reassembling machines (Holmgren, 2006). Maintenance teams also experience particular risks when they have to perform unusual tasks, possibly undertaken in confined spaces or at height (HSA, 2020). In industries including large kitchens and catering services such as the hospitality and healthcare industries, additional risks relate to electrical and fire hazards in kitchens, as well as possible exposure to pathogens such as in outbreaks of Legionnaires' disease (HAS, 2020). There are also special guidelines for maintenance workers who may be exposed to mould which may be found in buildings needing repairs (NIEHS, 2005).

2.4.5 Accident Prevention

Accident prevention is a challenging, multidisciplinary field, involving managerial as well as technical sciences (Holmgren, 2006; Lind, 2009). According to Kjellan (1984) various types of data are important for the prevention of accidents. These include: i) data with descriptions of accidents; ii) probabilities of incidents, their outcomes and consequences given a particular

deviation taking place and iii) the probabilities of hazardous deviations from the norm. The WAIT (Work Accidents Investigation Technique) process includes nine steps, the first of which collects information on all factors in a table (Jacinto and Aspinwall, 2003).

Accident theories emphasize the role of management, indicating that inadequate supervision, a lack of quality controls and poor instruction together with unsafe work practices all contribute to accidents (Reason, 1997). This implies that improved practices across all of these areas may be critical to accident prevention, although ultimately human error may also often be implicated (Reason, 1997; Lind 2009). Most theories, however, do not specifically emphasize the crucial importance of implementing safety standards.

Accident models form the basis of accident investigations (Kjellan, 2000). Developing Health and Safety legislation has meant that more commonplace accidents are also being investigated, providing more data. The Finnish model for accident analysis (Tuominen & Saari, 1982) is a widely cited basic model, illustrating how various contributing factors build an event together that leads to injuries. However, the literature discussing this model does not relate to maintenance departments in SMEs.

Hollnagel's model of accident prevention focusses on providing barriers between the hazard that may cause an accident and the people/ structures that need protecting (Hollnagel, 2004). Effective barriers may be established through managerial directives as well as technical safeguards (Lind, 2009). Skroumpelos (2009) assessed the effectiveness of management measures implemented in an attempt to prevent accidents. He introduced a new behavioural factor into the chain of events causing accidents, which he termed 'unsafe mentality bonding'. In his large-scale investigation into incidents occurring related to maintenance activities, he found three factors related to management to be lacking in cases of accidents: a) health and safety systems, b) adequate communications and c) means of enforcement. All of these need to be in place to ensure that the organization holds the correct knowledge, communicates it to all individuals conducting maintenance work and has correct controls and supervision in place to ensure implementation of up-to-date safety guidelines. As discussed in section 2.5 the existence of the knowledge alone, does not ensure its implementation. The various accident models, indicating the involvement of management issues as well as human error, highlight the importance of supervision, training and updated work guidelines. None of the studies to date have focused on the inclusion of information from standards in maintenance work guidelines.

2.5 Theoretical framework of Theories of Knowledge for a Research Practitioner

2.5.1 Knowledge Management, Creation and Transfer

The double loop theory of learning originated by Argyris (1976a) was fundamental to my decision that theories of knowledge, knowledge creation and knowledge transfer would be important to my thesis (see also section 4.2.4). In his theory of double loop learning, Argyris (1976a; 1978) emphasized the importance of critiquing assumptions regarding values and behaviour in place in organizations, so that learning would not only implement existing knowledge but also question the knowledge in use, so that new and more relevant knowledge may be created and transferred. His modes of learning theories (Argyris,1976a) also emphasize the importance of involving personnel in the assessment and creation of knowledge, in order to promote feelings of ownership and cooperation amongst personnel, reducing conflict and negative aspects of competition between personnel within the organization and shaming that may lead to reducing incentive to actively promote learning. As a research practitioner embarking on multi-grounded action research aiming not only to organize existing knowledge included in safety standards in such a way that facilitates its transferal to all relevant personnel, but also to change attitudes towards safety standards and also to change widely held assumptions about accident causation (discussed in section2.4), I became aware that theories of knowledge creation, knowledge management (KM) and knowledge transfer would be particularly important for building a theoretical framework for the study.

While organizing and passing on knowledge have always been essential aspects of businesses, KM is a relatively new field (Hansen, Nohria and Tierny, 1999), that is now recognized as an essential aspect of business organizations (Nonaka & Takeuchi, 1995). Although KM is often discussed in terms of maintaining a competitive edge, it is also essential for effective performance, with knowledge being recognized as one of a company's most important intangible assets (Patriotta, 2003; Ramirez et al., 2011). Developing the best practice for transfer of knowledge across boundaries, an essential aspect of KM, (Farnese et al., 2019) is particularly relevant to this study, as the existence of tacit or implicit knowledge at one place, even if it may be within the particular organization, does not necessarily ensure that the knowledge has reached those expected to implement it in practice. Furthermore, the quality of the organization's knowledge is of particular relevance (Chakrabarti, et al., 2018).

Nonaka and Takeuchi's SECI model (Socialization, Externalization, Combination, Internalization) became the gold standard, or most influential theory in knowledge creation and KM, in that it emphasizes the dynamic nature of KM (Bandera, et al., 2017; Nonaka & Takeuchi, 1995; Patriotta, 2003). The model was developed in Japan, based on Japanese cultural and industrial experience where employees may remain in one company for life, and was developed further to include the Japanese concept of *Ba* or place (Farnese et al., 2019). In the SECI model KM is regarded as a continuous process, involving ongoing identification or sourcing of knowledge, its refinement, use, storage and dissemination (Adesina & Ocholla, 2020). This aspect of the SECI model is problematic for organizations with high turnover of staff. Maintenance departments of SMEs in the west, especially when outsourcing is used, typically have high staff turnover rates. Engagement with SECI heightened my awareness that without novel interventions there may be a breakdown in knowledge transfer, which may be involved in accident causation. This also increased my determination to introduce new ways of KM which bypass this problem, including incorporation of tables of standards and simplified explanations into work guidelines. The model also stresses that KM is not the same thing as information management, an important point for ensuring dissemination of critical knowledge (Bandera et al., 2017).

In many organizations, knowledge may exist in an explicit or written form, or in a tacit form that is not formally recorded (Bandera, et al., 2017). Recognizing the tendency for existing knowledge not always being recorded in an organized and easily retrievable fashion, has enabled practice orientated theoretical frameworks to be built, with the existence of tacit unformulated knowledge often laying at the heart of problems of knowledge transfer, and indeed at the heart of this study. An important aspect of the SECI model is the emphasis on organizations being able to make tacit knowledge explicit by externalizing it. Knowledge is converted from implicit (or tacit) to explicit by going through a process of socialization, externalization, combination and finally being reinternalized, allowing an ongoing cycle of learning and dissemination of knowledge (Adesina & Ocholla, 2020; Farnese et al., 2019). Knowledge may only be effectively communicated when it is explicit and disseminated throughout the organization.

During the first decade of the 21st century some shortfalls were pointed out in the SECI model (Martin & Root, 2009). Particularly strong criticism came from Gourlay, (2003; 2006) who claimed that there is no sound empirical grounding to the SECI model, with it being based on anecdotal evidence from Japanese industries alone, and not necessarily applicable in

different cultures. Martin and Root's (2009) literature review of the knowledge creation and of the acceptance and application of the SECI model of KM in the construction industry, which is in many ways related to maintenance industries, is of particular interest for this study. They highlight the original association between quality management and knowledge management. Like Gourlay, (2003) they also note that the SECI model had been largely developed using data from the car industry in Japan, which brings its application to other geographical areas and sectors into question. However, they suggest that the model is relevant for KM and learning through apprentice-mentor relationships, which make it more generally applicable.

Another limitation of the SECI model is reported to be its over-simplicity, indicating that knowledge transfer is a sequential process, which may not reflect real life situations. Strong, Davenport and Prusak, (2008) pointed out that knowledge can only be useful to organizations if they can actually learn from it, i.e., possessing the information is not sufficient to support learning. However more recently there has been increased support for the model. Bandera et al., (2017) found the SECI model to have made a major contribution to both eastern and western KM theories. However, with particular relevance to this study, Desouza & Awazu (2006) suggest that the SECI may not be fully applicable to SMEs in that while socialization may be an applicable process, it is possible that in these smaller organizations, internalization may not occur.

The difficulties of applying theoretical knowledge to real life systems and organizations in cogently expressed by John Mingers (2006) in his book, *Realising Systems Thinking: Knowledge and Action in Management Science,* when he stated: "Real time organizations do not fit easily into mathematical models – they have social and political dimensions" (p. 2). This seems as true for KM as for any other system. The factors that may impede learning, storage and dissemination of knowledge may be completely unpredictable and irrational. It seems particularly important for research practitioners to bear this in mind. Due to social factors and internal politics, things may never actually happen, simply because someone somewhere along the line holds a grudge and decides not to cooperate, or worse, actually sabotages the whole project. This means that adding a phenomenological approach such as soft systems methodologies (SSM) approach may be important in any KM theory, as SSM may have important applications in learning and meaning development tools (Checkland, 1983; Wilson, 2001). Nevertheless, it is important to remember that "we have no access to

what the world is, to ontology, only to descriptions of the world, …that is to say, to epistemology… (Checkland, 1990).

Theories of knowledge management also emphasize the need for a functionally efficient transfer of knowledge on a professional level on the one hand, and the complex situation facing researchers assessing organizational knowledge on the other. Furthermore, these theories help focus the researcher on what he or she is actually assessing, as knowledge and knowing are treated as two separate entities. The research practitioner has to be aware that an organization may possess knowledge, without individuals being cognizant of it. These insights are of crucial importance to the analysis of the data collected in this study on several levels. Firstly, there is a difference between knowledge which may be held in an organization and that which is actually known, understood and used. The analysis of the data had to separate between these two variables. Furthermore, this also influenced my decision to use a qualitative rather than quantitative study, with verbal descriptions rather than numerical data enabling the formation of a rich picture of the situation on the ground (see Hon et al., 2010; Booton, 2018). As suggested by Goldkuhl, (2020) this approach allows a balance between practical problem solving and knowledge production.

2.5.2 Organizational Knowledge, Organizational Learning, Knowing in Practice and The Learning Organization.

Theories of organizational knowledge, organizational learning and knowing in practice relate to knowing how to get things done in complex organizations, and maintaining organizational learning (Bui & Baruch, 2010; Cook & Brown, 1999; Gherardi, 2000; Orlikowski, 2002; Senge, 2006). These are all essential to this study, acknowledging as they do, the complex nature of learning in organizations. Earlier theories were based on a traditional epistemology of knowledge, meaning what knowledge was possessed, with this entity regarded as something static (Cook & Brown, 1999). However, in order to describe the development of knowledge in an organization, as occurs in a learning organization, an ‘epistemology of action’ is preferred over an ‘epistemology of possession’ (Cook & Brown, 1999). In diagnosing problems with machinery or assessing correct maintenance techniques the individual’s ‘hands on’ experience, the group’s amassed knowledge and the organization’s codified explicit knowledge are all important. Cook and Brown, (1995) refer to an epistemology of practice, meaning that doing actions or in other words people practicing a

specific discipline as part of their work, are important parts of learning. Pragmatists make knowing (as an action) rather than knowledge (as a possession) their primary concern, with knowing intimately associated with practice.

Furthermore, Cook and Brown also suggest that in order to understand the knowledge of organizations better, this knowledge should be regarded as being comprised of four different entities: explicit, tacit, individual and group knowledge. This division is similar to the SECI KM theory, although they base their understanding of the tacit/explicit divide on the work of Polyani (1983) whose work (and whose example regarding the tacit knowledge involved in riding a bicycle which people cannot verbalize) also influenced other KM theories. Both divides, between tacit and explicit and between individual and group, are helpful when working with an organization, as it would be a grave mistake to assume homologous levels of knowledge throughout any organization.

The importance of group or organizational learning has been appreciated more in recent years, and is discussed in terms of communities of practice as well as peripheral participation which includes apprenticeship learning, a very real aspect of organizations. Learning at the level of the organization (Argyris and Schon, 1978) has been the focus of much scholarly and practical discourse (Senge, 2006). In the second edition to his book "The Fifth Discipline" Senge describes what he had learnt from Dr W. Edwards Deming, a pioneer of the quality management revolution. Deming was convinced that what was needed was a 'transformation of the prevailing systems of management' which required 'profound knowledge' (Senge, 2006).

Senge's theories based on five organizational disciplines for a learning organization were further developed by Bui and Baruch, (2010) by applying a systems approach to create a model more applicable in practice. This approach was also taken by Caldwell, (2012) who emphasizes that organizational learning is attuned with systems thinking, but also with issues of practice and issues of power. As with Senge, Bui and Baruch (2010) emphasize personal mastery, which is dependent to some extent on personal values, motivation, discipline, vision, development and training. They also suggest that mental models are a prerequisite to organizational learning, with these being dependent on organizational commitment, leadership and organizational culture. The existence of these mental models may be a prerequisite for knowledge sharing and improved organizational performance. It therefore may be that the formulation of such mental models is crucial for the action research aiming to

introduce new knowledge and techniques into an organization. For this research I consider this idea of mental models to be key to the design and success of my coaching sessions.

However, it may be equally important for a practitioner to understand the patterns of interactions in teams or in organizations that prevent, disrupt or undermine learning (Senge, 2006). This may be due to defensiveness of individuals not wishing to admit what they don't know, and therefore not willing to participate in learning processes. If it is felt that not knowing important information is tantamount to failure, then there may be extreme reluctance to participate in research and coaching sessions of the kind undertaken in this study, and in learning processes in general. By contrast, if individuals accept that learning is a lifelong practice, then by projection organizations may also become learning organizations, continually seeking knowledge and aspiring to improve.

2.5.3 Theories of knowledge and knowing; knowing in practice and information use.

The difference between knowledge and knowing was emphasized by Orlikowski (2002). Beyond the dichotomy between knowledge and knowing it is also important to remember that knowing is not a function that occurs in a person, and then remains present, but rather is an 'ongoing social accomplishment' with this particularly being the case in complex organizations (Orlikowski, 2002). Basing her work on Giddens (1984) Orlikowski discusses knowing in practice as something continually enacted in people's everyday activities (Savolainen, 2009). This approach is critical when assessing whether a piece of information known theoretically is actually practiced. If a safety standard is known but not put into practice, it is important to know why it is not being implemented.

Savolainen, (2009) analyses the conceptions of epistemic work proposed by Cook and Brown (1999) and knowing in practice proposed by Orlikowski, (2002) synthesizing them into a holistic framework for the study of information use. As explained by Savolainen, (2009) a crucial aspect of seeking knowledge and learning is how the information gained is used. This lies at the heart of this study, with the step from knowledge acquisition and learning to the implementation of that knowledge being crucial for the implementation of safety standards in maintenance organizations, something that essentially determines whether accidents happen and lives are lost.

2.5.4 Social Learning Theory

While KM theories discussed above are relatively recent, they may be linked to Albert Bandura's behavioural theory of social learning (Bandura, 1989, 2005), in which he describes how people learn from interactions in social contexts through observation, imitation and modelling, while emphasizing that learning alone is not sufficient in order for performance to change (Macleod, 2011; Nabavi, 2012). In real world organizations, these processes will be continuing alongside more formally structured learning activities, and may in fact be the backbone of learning within an organization. Any action research project seeking to bring about increased awareness and organizational change needs to be aware of these processes. Social learning theory is capitalized on by the coaching adopted in this study, both within the coaching sessions themselves and as a means of disseminating topics covered in the coaching to other members of the SMEs.

Bandura's Social Cognitive Theory (Bandura, 1989, 2005) and the concept of Self Efficacy (Nabavi, 2012) also impact upon the processes involved in organizational learning, in that individuals with weak self-efficacy may avoid challenging tasks, while those with high efficacy are more likely to view complex activities as something to be mastered. The cognitive element of learning may therefore be key in whether the personnel in an organization fully engage with learning new tasks and skills. When the skills and knowledge are essential to safety, it would therefore appear that adequate self-efficacy may be predetermining factor for successful implementation of crucial standards. All planned coaching and training must take this into account.

Social learning theory has been utilized in promoting organizational performance (Harrison and McIntosh, 1992), as it may be considered that where group efficacy expectations are high, organizational performance may improve. If organizations are viewed as having memories and as being capable of learning, then the group expectation may be critical in achieving effective learning translated into knowledge and knowing in practice. The organizational culture therefore may be critical in all organizational learning processes. In terms of this study, creating positive attitudes towards the possibility of learning and applying information in complex standards was a vital first step for success in the action research.

2.5.5 The relevance of social learning theories in practice, a Community of Practice (CoP)and provocative theory

Following on from the discussions on the difficulties inherent to applying theories of knowing in practice I now consider the question of relevance of social learning theory to management practice and will then review the contributions of provocative theory in helping elucidate this relevance, pausing briefly to consider the concept of a Community of Practice.

As mentioned above, (2.5.1) real life systems and organizations do not fit neatly into mathematical equations, which creates difficulties when applying theoretical knowledge to management practice. This in turn creates challenges for scholars at the interface between businesses and universities. If they there is no relevance in practice, then the legitimacy of theoretical work in academia may be questioned (Starkey and Madan, 2001). A key element of relevance is that theories may only impact upon management, if user communities are aware of the research, meaning that systematic and effective methods of disseminating findings to business communities are required. While invested managers may enjoy reading about research for its own sake, the integration of theories and practice remains vital. Starkey and Madan (2001) suggest, following Gibbons et al., (1994) that there are two modes of knowledge with Mode 1 being homogenic, hierarchical, and rigid, being produced by discipline based scientific investigation while Mode 2 is transdisciplinary, heterogenic and transient, being more socially accountable and flexible. The Mode 2 approach to knowledge may be more relevant to the dynamic world of business management and more useful in changing behaviours, which as Argyris and Schon (1978) suggest should be at the heart of education. Knowledge relevant to business management should be part of a 'knowledge chain' wherein knowledge informs action and action becomes knowable when the links between cause and effect are better understood. Beyond this, how knowledge is disseminated, how companies access information and share their knowledge all remain critical concerns.

It is therefore reasonable that knowledge production will continue to shift towards interdisciplinary research in the context of application, problem-solving and greater collaboration, connecting a 'supply side of knowledge', (universities) with the 'demand side', (businesses). Practitioner research is uniquely poised to bring about effective rapid interplay between management theory and practice.

The relationship between academic theory, research and management practice is discussed innovatively by Ramsey (2011) who proposes the use of provocative theory to explore how

management may extract ideas from academic theories and apply them to their day-to-day practice. The emphasis of provocative theory is on the process through which theory promotes changes in practice. As stated by Ramsey, "a provocative relationship between academic theory and management practice locates management learning within social processes".

As suggested by Corrardi et al., (2010: 267) "one reason for the renewed interest in practice theories in organization studies is linked to the search for a non-rational-cognitive view of knowledge. Central to the practice perspective is acknowledgement of the social, historical and structural contexts in which knowledge is manufactured. Practice allows researchers to investigate empirically how contextual elements shape knowledge and how competence is built around a contingent logic of action". Furthermore, the concept of communities of practice (CoP) introduces many innovative perspectives such as the "the situatedness and sociality of practices and the central importance of practical know-how for work". Brown and Duguid (1991:41) viewed a practice-based standpoint as bridging the gap "between working and innovating. Orlikowski, (2000) writes about how practice-oriented research is useful in gaining a deeper understanding of the role of social practices while adapting to rapid technological change. Finally, Gheradi (2000:220-21) opines that 'Practice is the figure of discourse that allows the processes of knowing at work and in organizing to be articulated as historical processes, material and indeterminate'.

The innovative use of provocative theory to learning in practice suggested by Ramsey (2011) moves the focus away from creating theories about organization, to managers reflexively using ideas to improve their management practice (Ramsey, 2011:3). The important point is that Theory is not *for* academics. In a provocative use of theory, the theory invites or provokes a response or interplay, from managers. Using theory as either explanation or as sense making does not give theory such a dynamic role in management practice. If on the other hand, theory is provoking innovations, it is an inherent part of development and change to more effective management practice. In my action research study, a provocative use of theories should help achieve an active response involving progression towards the desired situation wherein safety standards are incorporated in an accessible way in maintenance work guidelines.

2.5.6 Summary of section 2.5 Theories of Knowledge and learning in practice

The research questions guiding the action research in this study relate to information, its accessibility, its conversion into knowledge and the translation of that knowledge into practice. From the beginning of the study, I was aware of two contrasting and conflicting positions existing with regard to safety standards. The first position relates to the exitance of the information itself. When surveying the safety regulations included in published standards, it became apparent that there is a plethora of information on the topic. Looking at the introduction to the topic of safety standards in section 2.5.1 it may become quickly apparent that there is no dearth of regulations relating to safety. However, the situation on the ground, relating to the knowledge and understanding of this information is completely different.

As adroitly stated by Mingers (2006) in the introduction to his book, real time organizations do not fit easily into mathematical models – they have social and political dimensions. The politics of organizational life means that sometimes people are unwilling to co-operate or share information, so even if some members of an SME were cognizant of regulations in published standards it does not necessarily mean that this information reaches all those individuals to whom it is relevant. It also means that not all organizations are equally willing to participate in and cooperate with action research endeavours. As also found by Mingers (2006) this was particularly the case if any threat to power was perceived. The soft systems methodology (SSM) developed by Peter Checkland (1983;1990) and others has been acknowledged to be most appropriate for interventions in organizations.

In other words, it is the dissemination of knowledge, both tacit and explicit, its internalization and externalization that are important, and many factors impinge on this apart from the formulation of theory. Throughout these processes it is important to be aware that practice is constantly evolving, in terms of technology, knowledge and structure. The learning organization adapts to change, taking advantage of collective experience and group knowledge, with this affected by cultural and personal values. Just as practice evolves, so too does the function of knowing, with this also affected by self-efficacy. The relevance of theory for practice was discussed, emphasizing the idea that a mode of knowledge that is transdisciplinary, heterogenic and transient, being more socially accountable and flexible, termed mode 2 knowledge by Starkey and Madan (2001) may be more relevant to practice than a traditional type of homogenic scientific knowledge. This touches on what role

education should be undertaking in helping improve business, which in terms of this study does not only relate to financial elements or competition.

All of the theories of knowledge and learning organizations are given a new perspective by provocative theory (Ramsey, 2011). The emphasis is taken away from theory in an academic environment focusing instead on the interplay between theory and managers. Theory may provoke innovation and so induce more effective management practice and improve the overall functioning of the business. The ultimate aim of this action research study is to bring about a generic change in the work methodology of maintenance departments in SMEs, so that crucial information from standards is incorporated in work guidelines before all maintenance projects are started. Awareness of social learning theory and provocative theory, enables the researcher to regard the project in the larger context of learning organizations and the critical role of interplay with management in order to better guide the action research and meet research objectives.

2.6 Summary of the literature review

This chapter started by briefly presenting legislation and theoretical frameworks of Occupational Health and Safety. It then discusses the setting of to the study, considering how the organization of maintenance departments impacts on maintenance management, maintenance strategies and the implementation of work guidelines. The complex world of safety standards for risk assessment and accident prevention in maintenance work is briefly introduced. While many models of accident prevention do exist, investigations reveal that major incidents related to maintenance work continue to occur. The inclusion of safety standards in work guidelines is meant to ensure that theoretical knowledge within an organization is translated into knowledge in practice, preventing these accidents. The chapter therefore reviews the theoretical framework relevant to the way in which knowledge is disseminated, internalized and externalized in business settings. This includes organizational learning, knowing in practice, information use and social learning theories. Provocative theory is also considered with its innovative role in synthesizing the theories of social constructivism and organizational learning. Regarding the role of theory to provoke increased management efficiency and as an inherent part of organizational development is critical if business management theory is to remain relevant.

Chapter 3 – Research Philosophy and Multi-Grounded Action Research

*We have no access to what the world **is,** to ontology, only to descriptions of the world, …that is to say, to epistemology… (Checkland, 1990)*

While building a research concept I found that for obtaining a result that could be implemented in organizational procedures I have to develop a contour that will surround the hurdles of the contradictions between imposed rules described in standards and legal requirements and the existing work methodologies, contour acceptable by all involved sides. This prospection led to my paradigm and philosophy for my research as described further.

3.1 Searching for a Research Paradigm

The high incidence of accidents occurring in maintenance departments of SMEs, described in the introduction to this study, is associated with the risk of continued loss of life. Therefore, the mandate given to me to conduct this research, was to adopt a research paradigm including a methodology which would bring about a significant change in work procedures in these maintenance departments. According to Lincoln and Guba (1985) a research paradigm includes four main sections: ontology, epistemology, methodology and axiology.

This research's paradigm may be considered to be pragmatic, multi-grounded research, based on empirical observations combined with the provocative application of previously derived theories. The qualitative findings of interviews conducted with maintenance managers, supervisors and personnel, led to an action research approach with interactive coaching sessions. The inclusion of input of personnel in the study was critical to recruitment of participants to the research.

3.2 Research Philosophy

3.2.1 My Ontological Stance

The term 'Ontology' is derived from the Greek word *Ontologia* which means talking about being. In effect ontology discusses 'what is', and by logical extention 'what is not'. There are two main ontological positions: positivism and interpretism. The differences between these two positions may be understood by considering the nature of the main questions being

asked: is the researcher attempting to access what he or she believes to be an aspect of a single universal truth, or does the researcher consider that all investigations are subjective experiences and interpretations. While positivism remains the prevalent ontological stance for management research (Johnson & Duberley, 2000), due to the nature of this Action Research based study I decided that it was most appropriate to take a pragmatic ontological stance, influenced by the work of Kurt Lewin, the orginator of Action Research, rather than a purely positivist viewpoint. Pragmatist ontology as applied to social science advanced with the work of John Dewey (Hildebrand, 2008). A pragmatist approach to ontology avoids the tension involved in the metaphysical debates on the nature of truth and our understanding of truth, by focusing instead on our practical understanding of what takes place in the world rather than on a dualistic view of the world (Patton, 2005). In other words, Dewey's ontologist philosophy was based on theory of the act (Frankel-Pratt, 2016), and holds that acts or habits are what constitute social reality (Hildebrand, 2008). Pragmatist ontology takes a flexible view of the nature of the world, regarding it as including continua rather than paradigmatic divides, allowing the researcher to embrace multiple world-views (Frankel-Pratt, 2016). This is of particular importance for research into organizations, where a pragmatist ontology and epistemology may enable knowing and learning to transform practice (Biesta, 2010).

The concept of ontology is also important to this research in an applied sense, as applied ontology deals with the organization of knowledge and data management. For example, since genomic sequencing has unveiled vast amounts of information on the nucleic acid sequences found in living cells of a multitude of species, the field of gene ontology has developed to attempt to organize and unify knowledge of this information (Ashburner et.al, 2000). Similarly, in Information Science, ontology-based information retrieval systems have been used to improve efficiency (Munir and Anjum, 2018; Thomas, 2018). Businesses also use conceptual frameworks or ontologies to unify shared knowledge across different branches (Hyder et al, 2017; Mikkroyannidis & Theodoulidis, 2010). In the context of this research, the ultimate aim of the work could be described as creating an ontology of safety standards used to organize and share information. Thus, both the ontology of the researcher in terms of an attitude to that which exists and an ontology of safety regulations are important concepts.

3.2.2 My Epistemological Point of View

The term ‘epistemology’ (derived from the Greek word ‘episteme’ meaning ‘knowledge’) may be defined as the relationship between the researcher and reality (Carson et al., 2001). Epistemological discussions involve how knowledge may be attained and what may be known (Hitchcock & Hughes, 1989). Crotty (1998) explains that ontological and epistemological issues tend to emerge together, and for this reason does not include ontological questions in those to be asked in determining a research paradigm, concentrating on epistemological questions instead. However, my research paradigm was also influenced by MGAR, and differed from the classical positivist approach wherein researchers remain detached from research participants, emphasizing statistical and mathematical techniques (Johnson & Duberly, 2000). The MGAR is qualitative rather than quantitative, in that the detailed answers given to the open-ended questions were the significant results, rather than any statistical analysis of numerical data. The provocative use of theories (Ramsey, 2011) of knowledge management (Hansen, Nohria and Tierny, 1999; Nonaka & Takeuchi, 1995 and organizational learning (Cook & Brown, 1999; Gherardi, 2000; Orlikowski, 2002) together with theories of health and safety (Pouliakas & Theodossiou, 2010) and accident prevention (Cooke, 2009; Hollnagel, 2004; Holmgren, 2005; 2006; Kjellan & Albrechtsen, 2017; Okoh & Haugen, 2014;) allowed the interviews to be conducted effectively. These theories helped ensure that as much relevant information as possible would be gathered on which standards were or were not being included in daily work guide lines; whether the standards were being implemented if they were included and if the standards were unknown, not implemented or not understood why this was the case. Understanding the complex wording and organization (or lack of organization) of published safety standards; the structure of maintenance departments and different maintenance strategies employed; the importance of failings in information and knowledge management including the social elements and importance of the externalization and internalization of knowledge; the critical role played by a safety culture as well as the role of social and behavioural theories in accidents were all important in devising the questionnaires. In line with Cook & Brown’s assertion that an ‘epistemology of action’ is preferred over an ‘epistemology of possession’ and ‘an epistemology of practice’ (Cook & Brown, 1995) is regarded as particularly relevant, as the knowledge held in maintenance departments is dynamic, and learning occurs through practice, while people are doing their jobs with guidance of how they do their jobs only becoming part of organizational learning if it is put into practice.

As stated above, in my pragmatic approach, influenced by the ideas of Kurt Lewin, understanding human behaviour was necessary to encourage active participation in the research and to assess which solutions may be successfully implemented in the field. This is in line with qualitative research guided by grounded theory, which emphasizes the socially shared meanings underlying individuals' behaviour (Milliken and Schreiber, 2012). This pragmatic approach is in line with an 'epistemology of action' or 'an epistemology of practice', and with the MGAR approach adopted for this study that finds a balance between practical problem solving and knowledge production (Goldkuhl, 2020). As explained in the previous chapter, while early theories of knowledge were based on a traditional static epistemology of knowledge, more recently an 'epistemology of action' has been adopted to describe the development of knowledge in learning organizations (Cook & Brown, 1999). Individuals' 'hands on' experience, and the organization's collected, codified explicit knowledge are both important. To describe this, Cook and Brown, (1995) refer to an epistemology of practice, whereby people practicing a specific discipline as part of their work, are important parts of learning. Pragmatists make knowing (as an action) rather than knowledge (as a possession) their primary concern, with knowing intimately associated with practice.

Pragmatism is often related to a mixed methods approach (Biesta, 2010), and I included some aspects of qualitative methodologies including a qualitative approach to conducting the interviews, eliciting and recording the answers follows on from the approach of grounded theory (Glaser & Strauss, 1967). While grounded theory was initially conducted without active input from research participants, the approach of multi-grounded action research was preferred, with active input from maintenance professionals sought in the interactive coaching sessions which formed part of the action research. In grounded research, collection of data is typically followed by some sort coding and writing memo notes (memoing) (Dick, 2003).

3.3 Pragmatism

Kurt Lewin, has been described as the father of pragmatism (Adelman, 1993). His methodology was influenced by C. S. Peirce, (sometimes known as the father of pragmatism) as being "a dialectical process seeking best fit or concordance and an interpretative (of many social perspectives) epistemologies melded to a quasi-experimental orientation" (Adelman, 1993). It seemed to me that when studying a business organization, while seeking changes in behaviour, that this approach was more suitable than classical positivism. John Dewey's work

was also critical in laying out the pragmatic approach to science, particularly in education (Greenwood and Levin, 2007). His eloquent criticism of the traditional separation of knowledge and action has influenced generations of researchers and practitioners in many fields and also laid the groundwork for this study.

3.3.1 Pragmatic Approaches to Grounded Theory: Constructivist Grounded Theory and Multi-Grounded Research: A Pragmatic Approach

The application of a pragmatic approach to the qualitative research methods of grounded theory led to the development of constructivist grounded theory (Charmaz, 1994). The understanding is that theories are not discovered through the qualitative observations of grounded research, but instead they are constructed by researchers as a result of their interactions with research participants. This develops grounded research in such a way that it combines well with the participatory approach of action research. In both cases the understanding of the situation being researched emerges slowly as further cycles of the study are undertaken (Dick, 2003).

In the grounded theory approach, the researcher is primarily involved in the systematic collection of data from which theory is inductively built. The gradual build-up of data and carefully recorded notes allow a detailed picture to be formed of what is taking place. The recognition that deductive application of previously constructed theories can and should be applied to a research scenario led to the multi-grounded approach (Axelson & Goldkuhl, 2004; Lind & Goldkuhl, 2006), combining empirical observations with other theoretical frameworks, or as stated by Lind and Goldkuhl (2006:72) “multi-grounded theory is an attempt to combine certain aspects from inductivism and deductivism, as a kind abductivism”. In other words, there is an attempt to systematically apply pre-existing theories to help think through and focus research questions, through a process of reflection and revision before starting the data collection or interview phase. The holistic emphasis on an organization as a whole allows for novel understandings of complex processes, with this approach being particularly relevant to this study. The accidents were not occurring in maintenance departments only due to technical failures of one specific type of equipment, or to a breakdown of communications in one area of the department, but by a problem occurring across the board in all SME maintenance departments: the failure to understand and implement safety standards. The interviews revealed what was happening and why it was happening, but an additional stage – that of action research based on interactive coaching

sessions with input from research participants was required to start resolving the problem and bring about much needed change.

3.4 Action Science

Action science is an outgrowth of the traditions of John Dewey and Kurt Lewin, although it is worth noting that the radical ideas of Lewin and Dewey remained largely untried until the late 1960s (Adelman, 1993; Argyris et al., 1985). While the ideas of Dewey were largely restricted to the field of education, the Lewinian tradition of action science, in contrast, has been influential in leading the way for scholar-practitioners in group dynamics and organizational science who have sought to integrate science and practice. Members of this tradition have emphasized the continuities between the activities of science and the activities of learning in the action context, the mutually reinforcing values of science, democracy and education and the benefits of combining science and social practice (Argyris et al. 1985). These concepts have been crucial for my approach to this study.

3.4.1 Action Research as a Transformative Process

One key element of action research is the participation of the people involved in the problem, who work together with the researcher in the effort to resolve the problem (Koshy et al., 2011). It was clear to me that in this case, that the maintenance personnel working with me could not only be passive participants from whom information was collected during interviews. Their active input would also be necessary to ensure that information was rephrased in a way accessible to them and to all other personnel in maintenance departments.

A second key element is the concept that social systems constantly undergo change, and that the researcher, alongside the other participants, can be a part of that change (Greenwood & Levin, 2007). While change may occur gradually within organizations, I felt and still feel that a catalyst that may speed up change towards safer work practices remains essential in maintenance departments in SMEs. Action research itself has been viewed as a catalyst for change (Steensgaard et al., 2020; Shmuck, 2006), although from personal experience it may be said that putting this change into practice may be a prolonged, challenging and sometimes frustrating experience.

A third key element of action research is that it involves a spiral consisting of several cycles each with several stages. These stages are: planning an action that is hoped will initiate change; implementing the planned action and observing the results of that action; reflecting

on the process followed by re-planning; acting and observing again, and continuing with further reflection (Hopkins, 1985). My research goal tied in completely with that of action research, which is to see change occurring in everyday practice.

3.4.2 Action Research in Practice

There are two leading questions around which the action research in this study has been planned. Firstly: "Which sections from standards and regulations must be cited in work guidelines for particular maintenance jobs?". This is a complicated question as there are hundreds of official standards relating to maintenance work, each one with multiple sections. Many of the sections also include references to further sets of regulations. The second question asks: "Which of these standards and regulations are currently misunderstood by team leaders and other maintenance professionals and must be rephrased so that the regulations can be followed?" In Action Research, cycles including planning action, taking action and evaluating the action before continuing the research and repeating the cycle are conducted, in a construct-plan-act-evaluate cycle. The first action to be taken in this study is to rephrase the sections of crucial information contained in standards and other regulations that are being misunderstood. The next action is to conduct coaching sessions which revolve around explaining this rephrased material. This should continue in a repetitive basis at selected intervals of time as new standards and reguilations are introduced, and according to organizational needs.

3.4.3 Multi-Grounded Action Research

Multi-grounded action research (MGAR) is an approach that offers a balance between carefully conducted qualitative research in the field, creating a rich picture of what is taking place on the ground, (following Monk & Howard, 1998; Booton, 2018) while also taking existing theories into consideration, and then working together with research participants to resolve problems and find solutions in cycles reassessing the situation each time possible solutions are attempted. It is suggested by Goldkuhl et al., (2020) that it offers a balance between practical problem solving and knowledge production, ensuring an active use of theory both by induction from the grounded research and deduction from existing theories during the process of bringing about organizational change.

3.4.4 Implementing Change through Multi-Grounded Action Research including Interactive Coaching Techniques.

The support provided by action researchers in attempting to implement change may include training or coaching (see section 6.1.4). The research on coaching techniques which actively involve participants indicates that the active interchanges between trainer and trainee allows for clarification of all concepts through question-answer sessions (Arnold, 2009). Coaching techniques relevant to this study include those presented by Atkinson, (2012), and Carter, (2015), Hawkins and Petty (2000). As noted by Atkinson (2012) coaching focuses on moving from simple to complex learning. Hawkins & Petty (2000) further emphasize that when conducted in conjunction with an action plan and on-going analysis of results, coaching can bring about a change in behaviour.

Chapter 4 – Research Design

4.1 Overview of the Research Design

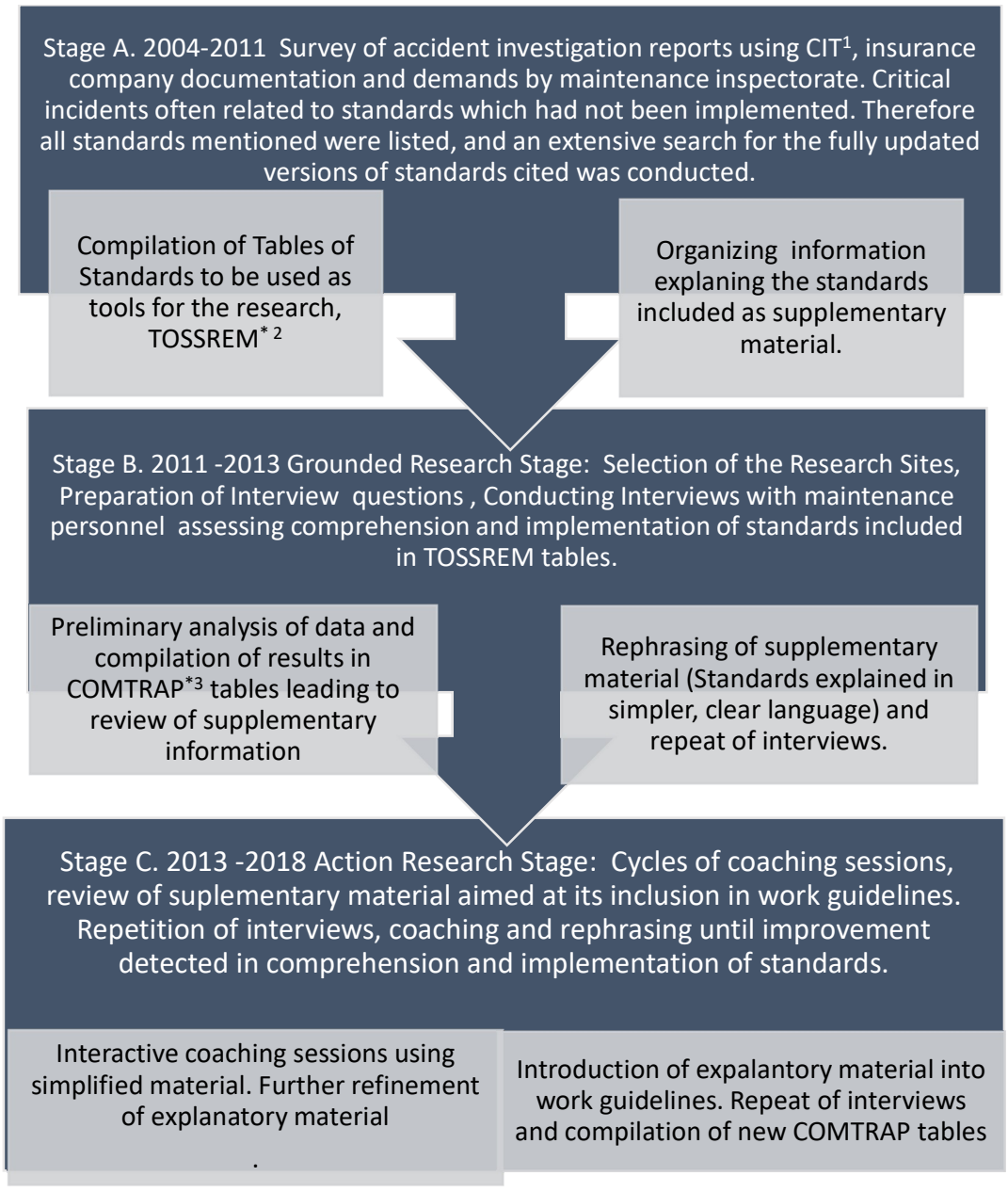


Fig. 4.1 Overview of the Research Design

*[1] Critical Incident Technique

*[2] TOSSREM Table of Standards Relevant to Maintenance Work;

*[3] COMTRAP Compliance with Compliance with Tables of standards by different professionals

4.1.2 The three stages of the Research

As shown in figure 4.1 the research was conducted in three stages, consisting of:

- Preparatory Survey Stage A: The starting point of the research was a survey of personal communications from colleagues who had conducted investigations into accidents related to inadequate maintenance work and reports published by insurance companies and safety inspectors. During the survey I was looking for commonalities between cases. After noticing that many reports by insurance companies and safety inspectors noted safety standards that had not been followed, reports were reviewed again noting all references to standards cited that had not been implemented. Some of the investigations into the accidents had included interviews based on the principles of critical incident technique (CIT) (see section 4.2.2). These interviews yielded rich descriptions revealing that critical incidents leading to accidents could have been prevented had up to date safety standards been followed in work procedures. An extensive search was then conducted to find all the various parts of standards referred to (sometimes appearing in different publications as they had been updated at different years) and these were collated into tables of standards relevant to maintenance work (TOSSREM).
- Multi-Grounded Research Stage B: In order to conduct a broader study into work practices in maintenance departments in general, and not only investigating what had happened at sites where large-scale accidents had occurred, a study was designed based on multi-grounded research including qualitative interviews. The study was not purely based on grounded research principles as it also assessed previously developed theoretical frameworks using provocative theory (Ramsey, 2011). That is to say, the questions were not restricted to those asked in any previous studies, and previous accident investigations. This stage included selecting research participants, writing interview questions, conducting interviews, recording answers and compiling tables related to compliance with standards according to profession (COMTRAP). Explanatory material was written to accompany the tables.
- Action Research Stage C: Active input from research participants was sought while conducting interactive coaching sessions. These sessions were aimed at refining the explanatory material, ready for introduction into daily work guidelines. Interviews were repeated assessing the impact of the rephrased material on comprehension and implementation of standards.

4.1.3 Research Design Consideration: Qualitative Research

As explained in the introduction, previous quantitative investigations into why maintenance work was resulting in fatal accidents had failed to provide a solution to the problem. I therefore committed myself to a qualitative study based on interviews with personnel working in maintenance departments, which were designed to include open ended questions that could elicit answers including rich descriptions of what was taking place within the departments. I included elements selected from various studies of accident analysis, bearing in mind the principles of CIT discussed in section 4.2.2. Some aspects of the interviews were

derived from Gyekye, (2006) who investigated the influence of workers' perceptions of the hazardous nature of their environment on their behaviour, using interview questionnaires, with answers recorded on a likert scale. The technique of using more extensive interviews to get a rich picture of the situation was adapted from Hon et al., (2010) who used a mixed approach of qualitative methods based on semi-structured interviews with senior management representatives, transcribed into narratives to analyse the causes of accidents in maintenance work in the building industry. They also added a quantitative element by ranking the importance of various factors. The element of placing the emphasis on prevention of future incidents in accident analysis was adapted from Leplat & Rasmussen, (1984).

The survey of reports that formed the first part of the study, gave rise to the theory that safety standards are often not implemented in maintenance work, and this was the underlying reason for the high incidence of maintenance-related accidents. The methodology combined aspects of multi-grounded action research, critical incident technique and provocative theory. In the multi-grounded action research conducted in stages B and C of the study, the theory developed during the first stage of the study, that not implementing safety standards was the cause of accidents, guided the rest of the study. The emphasis was placed on finding out the parameters of this phenomenon. To what extent were standards not being implemented? Is this a daily occurrence or a rare event? Is this something that team leaders and managers were aware of? Is there a difference in implementation of standards between different types of maintenance personnel and between different types of maintenance sites? The evidence collected in the interviews was then fed into the coaching sessions. The overall aim was to reach a situation whereby the behaviour of maintenance personnel no longer resulted in accidents.

4.2 Preparatory Survey Stage A:

4.2.1 Review of accident investigations, insurance documentation and reports by safety inspectorates

In order to gain a fuller understanding of investigations previously carried out into accidents related to inadequate maintenance work, I chose to begin by locating, collecting and analysing the three types of documents: i) Reports of accident investigations; ii) demands by insurance companies including directives to be complied with in order for insurance to be

valid and iii) documents detailing demands by safety inspectors and any other authorities inspecting maintenance work.

One problem that arose was that the bulk of investigation reports are devoted to issues related to costs. These included the costs caused by the accidents; the costs of work intended to prevent accidents and the costs resulting from the accidents. This was not helpful in assessing what had caused accidents, but meant there was a large volume of material to be sifted though. However, some reports included interviews with workers which had been carried out according to CIT methods (see section 4.2.2).

These reports all cited numerous standards that must be implemented when various types of maintenance work are undertaken. However, in almost all cases the personnel interviewed who had conducted maintenance work at sites where accidents occurred, did not mention many of the standards deemed essential for safe work practices. Furthermore, a closer reading of the descriptions of work practices revealed that these did not match instructions included in standards defining how these tasks should be undertaken. In short, in all cases where rich descriptions of work methods in maintenance sites were compared with demands made by insurance companies related to the same site, together with reports by safety inspectors, I noticed that various safety standards had not been implemented when accidents had occurred. When I reviewed the investigation reports again, I noticed a clear pattern connecting the lack of implementation of standards with the rise in incidence of accidents associated with maintenance work. This concept guided the entire research study.

4.2.2 Critical Incident Technique

Critical incident technique (CIT) proposed by Flanagan (1954), was used by some interviewers assessing the accidents related to inadequate maintenance. In CIT interviewers do not guide interviewees in any particular direction, thereby allowing answers to arise that include information that may not be revealed when using more structured interview techniques with closed questions (Flanagan, 1954; Snodgrass et al., 2009; Bott & Tourish, 2016). Retrospective interviews of this type have been used in more fields to reveal ‘critical’ events previously misunderstood or left unresolved over the last few decades (Butterfield et al., 2004; Gremler, 2015). With protocols available outlining a step-by-step approach to collecting and analysing information, CIT is now considered to be reliable method for qualitative research into significant events (Hughes, 2007; Woolsey, 1986).

CIT includes five steps which can be briefly summarized as: 1) determining the general aim of the activity being investigated; 2) agreeing on precise specifications when collecting data; 3) collecting the data itself often through interviews; 4) analysing the data; and finally, 5) reporting the findings (Flanagan, 1954; Cunningham, De Brún & McAuliffe, 2020). The interviews I conducted in the study sought information on continuing patterns of behaviour rather than information on one particular incident, whereas CIT is often used to reveal information on one particular incident. However, some aspects of CIT interview techniques remained relevant for this stage of the study. For example, one important aspect of CIT is that the person interviewing participants may be considered an expert observer, enabling them to judge the importance of the information being given (Flanagan, 1954). This is crucial in order for all essential information to be present at the analysis stage. Interviews based on CIT indicated that various standards had not been implemented when accidents occurred. This gave the direction to the rest of the study.

4.2.3 Creating a Rich Picture of Work Conducted by Maintenance Departments

In order to identify which standards are not being implemented throughout the spectrum of tasks undertaken by maintenance departments, lists of these tasks had to be drawn up. To this end a brainstorming session was held together with the professionals accompanying the research from MATI (all with legal and business backgrounds). To start with a large chart of all activities was drawn. The members of the MATI teams accompanying the study then added more detailed information gained from questions that were asked in various accident and insurance investigations carried out in interviews following accidents in the organizations they work with. Gradually a comprehensive picture of each job was compiled. I could then add the legal standards and regulatory requirements that apply to each section of each task.

4.2.4 The Double Loop and Reverse Engineering.

Argyris coined the terms ‘single loop’ and ‘double loop’ to explain the difference between two different types of learning (Argyris, 1976a: 5-7). The single loop just involved learning about a certain behaviour, while the double loop also involved learning ***why*** a new sort of behaviour was needed in that the initial values and objectives are questioned (Argyris, 1976a). Argyris’ double loop theory has been related to solving complex problems with poorly defined structures, involving people’s behaviour, as there is often a difference between

what people believe they are acting on (espoused theory) and the actual theory they are following (theory-in-use) and effectiveness results from congruence between the two (Argaris, 1980). Understanding behaviour may need a two-pronged approach, to account for this divide (Argyris, 1976b; Argyris & Schon, 1978; Argyris, Putnam & McLain Smith, 1985). I needed to prove it, to understand **what** was happening (the extent of the problem) and **why** it was happening, something that also involved questioning whether objectives in place were in fact the correct objectives (Argyris & Schon, 1978:2-3). I therefore decided that this study would be designed according to a double loop multi-grounded action research concept. In this case, the first loop involved discovering ***what*** was being implemented in maintenance departments, including which information contained in standards and regulations had not been understood. The second loop involved understanding ***why*** the information had not been understood, whether or not it was an objective of maintenance managers to explain this information and what could be done to improve the situation.

Furthermore, as a researcher who is intending to bring about organizational change, and as Judi Marshall had pondered in her paper, *Living Life as Inquiry*, I was interested to find out 'how much influence an individual can have on organizational and other systems' (Marshall, 1999:156). If the study is ultimately successful in raising awareness as to the importance of following standards, and in making tools available to enable standards to be followed so reducing accidents, then that would be encouraging with regard with the potential of an individual to influence organizations and make a change. In order to avoid drawing irrelevant or impractical conclusions which could not be implemented in the field, every phase of the study was completed in collaboration with the people who would eventually implement the conclusions. Once again, in common with Marshall, (1999) I was dealing with living people and processes, which were constantly undergoing change, and checking to see how its input could also bring about change in the desired direction. This necessarily involved continued questioning, assessment and reassessment.

Having a background in engineering I was very familiar with the 'reverse engineering' approach (Raja & Fernandes, 2008), in which one starts with a finished product, (or in this case situation) and take it apart to discover how people reached this product (or situation). Although I was convinced that people were not implementing safety standards, and that this was the root to the cause of many accidents, the interviews were designed to allow me to learn the extent of the problem and why this was happening.

4.2.5 Mapping citations of standards

When trying to ask maintenance workers about their familiarity with standards, one of the problems that needs to be overcome is that a huge body of safety standards exists, which has been called 'a massive and mysterious universe' (Cheit, 1990, p.21). For example, in 1983, the National Bureau of Standards created a directory of private standards which included 32,000 standards submitted by about 420 non-government bodies (Cheit, 1990). One must add to those the British and European standards, and the many additions since 1983 to get a better picture of the complexity of the field. The Standards published by various organizations also often include cross indexing to Standards published elsewhere. One has to follow the trails of the cross indexing, often leading to updates published over many years, in order to assemble the full standard. Furthermore, even once a review of standards is completed, it has to be continually updated as new guides are published and standards are updated individually too.

In order to investigate exactly which standards were reported as not having been implemented when accidents took place, and then ask maintenance personnel whether they understood and implemented these standards in their work, I needed to create a reference list of standards. The reports I reviewed in the first stage of the study often cited standards in the most minimal way, by reference numbers. Finding the full standards from these reference numbers is not simple. There are many standards organizations in the world and most of these organizations formulate standards covering a multitude of things from defining the size and acidity of olives before canning them, up to the level of radiation that can be diffused by atomic fuel rods. The diversity is tremendous, but here we are only interested in standards imposed by authorities on organizational maintenance departments.

While narrowing the field, this still left an enormous number of standards. Recently composed sets of standards relevant for maintenance departments include the environmental sustainability and energy performance improvement, efficiency, use and consumption standards (ISO 14001/ISO 50001) and the risk assessment and management standards IEC/FDIS/ISO 31010, ISO/IEC/ISO 31000. These families of standards focus on improving energy performance, efficiency, use and consumption. They allow maintenance departments to systematically identify and manage their environmental impacts in the broadest sense as required by environmental authorities. In general, these standards include guidelines on how to improve energy use and sustainability. They also set out guidelines on how to reduce environmental pollution. When combined together with ISO 14001, the 50001 and 31010

standards supply organizational maintenance departments with directives on how to manage tasks to reduce power use without increasing risks of power loss and thus to stay “clean” with this being regardless of whether their personnel are outsourced or permanent employees. But, as is described in the forwards of the standards, the standards also aim to improve safety. The risk management standards include instructions on properly conducting risk analysis work procedures as well as guidelines on reducing pollution and minimalizing energy use, while maximizing energy efficiency.

The second group of standards imposed on maintenance work are the series IEC 61000 Electro technical standards and IEEE/ANSI/NFPA 70 National Electrical Code being a group of more than a hundred of standards focused on safety concepts existing for the maintenance personnel. They also direct attention to the safety of the general public. There are specific paragraphs relating to cases of malfunction or emergency occurrences in the IEC 61000 Electro technical standards and IEEE/ANSI/NFPA 70 National Electrical Code.

In most cases an individual standard was initiated after an accident led to an investigation, which in turn concluded that the accident could have been avoided if proper instructions, imposed in a Standard, had been followed. According to legislation it is forbidden for unaccredited bodies to modify, add to or detract from any part of a standard, even by a single word. Only statutorily and officially recognized bodies designated to study, adapt and publish standards are allowed to do so by using professional specialist committees officially appointed to execute the task. In many cases the language used in those standards is very professional and contains complicated technical descriptions making it nearly unusable for the general public.

As the authors of the standards use a highly technical vocabulary, they are not easy to understand, with only highly skilled professionals being familiar with all of the terms used.

The guides which I used to locate the full standards are shown in table 4.1. Some of these guides are horizontal publications. The fundamental concept of a horizontal publication is that it is an international publication that is widely applicable and to be used by all relevant committees and that has undergone an enhanced approval process as described in the document. In the guides the term "committees" includes technical committees, project committees, subcommittees and systems committees. The term "publication" includes International Standard, Technical Report, Technical Specification, Publicly Available

Specification and Guide. The term "product" is used to refer to individual products, processes, services and combinations thereof, commonly known as "systems".

Some of the official standards were cited by the names of the investigations which recalled them, rather than by their reference numbers. It was therefore necessary to devise a way to divide the accident reports according to the standards cited within them. There was a tremendous volume of material. Using these Guides, a long list of standards was compiled following their references in the different statutory documents or in accidents' investigations, as well as in the conclusions and recommendations of the reports. Eventually this list included 320 full length standards that were identified as being relevant to maintenance work and noted.

Table 4.1 The guides covering all specific standards for this research:

1	IEC GUIDE 108	Defines the relationship between horizontal standards and product publications. It specifies procedures for the designation of horizontal standards and for their use. According to the International Electrical Commission, the guide "is to be used in conjunction with the ISO/IEC Directives and with the aspect-specific Guides.	Most recent version published in 2019.
2	IEC GUIDE 104	A mandatory guide defining and specifying safety procedures including and in addition to the ISO/IEC Guide 51, which includes a group of standards describing and defining the safety of persons, domestic animals, livestock and property	The current version published in 2019.
3	IEC GUIDE 107	Guides the drafting of electromagnetic compatibility (EMC) publications; specifies and describes the standards related to electrical and electrotechnical components and assemblies specifically described in the IEC 61000 standards group and more. These standards and guidelines are applied when preparing new electromagnetic compatibility publications to ensure consistency	The current version was published in 2014.
4	ISO Guide 73	The requirements for risk management packages together with the generic terms used in these documents, seeking to arrive at a uniform use of risk management terminology. To be used by public or private organizations requiring a detailed risk assessment process before starting the activity as described in the ISO 31000 and ISO 31010 standards families.	Composed 2009 Reviewed 2016
5	ISO 14000	Family of standards about environmental management, providing practical tools for companies and organizations required to manage their environmental responsibilities according to mandatory imposed regulations and rules.	

For professionals using the standards, and for the researchers looking into implementation of the standards, it is important to realize that there is a distinction between the requirements directed at the professionals who build, install and maintain the systems and requirements directed at protecting unskilled users of the same systems, i.e., the general public. It is

assumed that the public are unaware of the dangers of using the systems. Emphasis is therefore placed on requiring professional authorities to take any actions necessary to protect the public. The standards however are only directed to what are considered to be dangers that may arise from normal use, based on the system's designation. In most SMEs, the general public may use many systems without them being aware of the possibility of dangers from this use. The organizational maintenance personnel are responsible for performing the actions described in the standards that will ensure the public remain safe while using the systems. This once again underlines the importance of these professionals understanding and implementing all of these regulations.

4.2.6 Filtering the long list of Standards

The 'long list' of Standards gathered in the first phase of this research included 320 full length standards with all of their subsections. This was too long to be of practical use in the study. To avoid my bankruptcy (because if I personally purchased all of them according to standards institutes' requirements the total price of buying copies would be over a few hundred thousand Euros), I used the Israel Standard Institute library to study these standards, and copy and use parts that are allowed to be freely used and quoted.

The long list was not one of the goals of this research, but a necessary stage towards reaching a manageable document with a list of relevant standards to be used in the multi-grounded action research. The long list had to be filtered in order to collate a table of standards including the information needed in an accessible way.

I used the soft systems methodology (SSM) (see Checkland, 1983, 1990; Patching, 1990; Wilson 2001) aimed at sorting the necessary information from the standards found in the preliminary stage of the study reviewing the accident investigation documents. While ensuring that all necessary standards would be included, I could discard duplicates, and combine subsections of standards under the heading of 'leading standards'. This allowed me to *"separate the wheat from the chaff*" supplying the necessary standards without overflowing the research with information that was not critical. I did not want to arrive at a situation where the *wood* was hidden by many superfluous *trees*. I therefore conducted a thorough search for common denominators within the standards. In order to ensure that the study would be relevant to all parts of the maintenance departments, and not only to specific professions within the department, these common denominators needed to be wide enough to be relevant across the various maintenance professions, so great care had to be taken that these common denominators would be applicable across the board to all maintenance

professions. Finding these common denominators was later useful in phrasing interview questions in a way that was relevant to all of the professions.

Once the common denominators were found and listed, the standards could be mapped. This involved linking each narrowly defined standard to a 'leading standard'. A list of 'leading standards' was compiled. This list of leading standards relevant to maintenance departments formed the basis of the research. These leading standards were then organized into families. Once each regulation cited was linked to a leading standard, they were then sorted according to the regulations' relevance to a particular profession or to a specific part of that profession. Sorting the standards in this way, also allowed me to avoid unnecessary repetitions, and reduce the number of standards in the study to a realistic number for the research.

4.2.7 Collation of Tables of Standards Relevant to Maintenance Work -TOSSREM

The list of standards and regulations included in the TOSSREM (See table 4.2 for a list of standards and their contexts with abbreviated descriptions of the field each standard applies to and see Annex 2 for the full table including the definitions of the area of reference) covers the tasks carried out in maintenance departments with an emphasis on the families of standards covering safety, risk assessment, environmental protection, ethical sustainability and social impact.

The Standards are organized according to their reference numbers, with those relating to similar areas being grouped together. Thus, the first seventeen groups of standards relate to electromagnetic compatibility ranging from fundamental definitions and terms, voltages, effects of high-power electromagnetic installations on civil systems, environmental compatibility levels and limits for emissions among others.

Other standards also relating to electrical systems relate to harmonics, metering equipment and voltage dips. Further groups of standards relate to risk assessment, giving management guidelines for risk assessment; quality management; measuring energy performance; and environmental management.

Table 4.2 The list of Standards - TOSSREM

Standards Relevant to the Safety of Maintenance Work

IEC/TR 61000-1-1	Electromagnetic compatibility (EMC) - Part 1: General - 1: Application and interpretation of fundamental definitions and terms
IEC/TR 61000-2-1	Electromagnetic compatibility (EMC) - Part 2: Environment - Section 1: conducted disturbances and signalling in public power supply systems
IEC/TS 61000-2-5	Electromagnetic compatibility (EMC) - Part 2: Environment - Section 5:
IEC 61000-3-3	Electromagnetic compatibility (EMC) – Part 3-3: Limits
IEC/TR 61000-1-4	Electromagnetic compatibility (EMC) – Parts 1-4: General -
IEC/TR 61000-1-5	Electromagnetic compatibility (EMC) - Part 1-5: General
IEC 61000-2-2	Electromagnetic compatibility (EMC) - Part 2-2: Environment -
IEC 61000-2-4	Electromagnetic compatibility (EMC) - Part 2-4: Environment -
IEC/TR 61000-2-8	Electromagnetic compatibility (EMC) - Part 2-8: Environment
IEC 61000-2-9	Electromagnetic compatibility (EMC) - Part 2-8: Environment
IEC 61000-2-10	Electromagnetic compatibility (EMC) - Part 2-10: Environment
IEC 61000-2-11	Electromagnetic compatibility (EMC) - Part 2-11: Environment
IEC 61000-2-12	Electromagnetic compatibility (EMC) - Part 2-12: Environment
IEC 61000-2-13	Electromagnetic compatibility (EMC) - Part 2-13: Environment
IEC/TR 61000-2-14	Electromagnetic compatibility (EMC) - Part 2-14: Environment
IEC 61000-3-2	Electromagnetic compatibility (EMC) - Part 3-2: Limits for harmonic current emissions
IEC 61000-3-3	Electromagnetic compatibility (EMC) - Part 3-3: Limitation of voltage changes,
EN 50160	Voltage characteristics of electricity supplied by public distribution system
G5/4-1 – ENA	This standard specifies harmonic current emission limits.
IEEE Std 519	Recommended Practices and Requirements for Harmonics Control
IEEE 1159	Recommended Practice for Monitoring Electric Power Quality
IEC 62052-11	Electricity metering equipment (AC) - General requirements.
IEC 62053-11	Electromechanical meters for active energy
IEC 62053-21	Electricity metering equipment (a.c.) - Part 21: Static meters.
IEC 62053-22	Electricity metering equipment (a.c.) -Part 22: Static meters.
IEC 62053-23	Electricity metering equipment (a.c.) - Part 23: Static meters for reactive energy (classes 2 and 3)

IEC 60050-131 , IEC 60050-161 , IEC 60065 , IEC 60107-1 , IEC 60155 , IEC 60268-3 , IEC 60335-2-2 , IEC 60335-2-7 , IEC 60335-2-14 , IEC 60974-1 , IEC 61000-2-2 , IEC 61000-4-7, IEC/TS 61000-3-4 , IEC 60050-131 , IEC 60050-161 , IEC 60065 , IEC 60107-1 , IEC 60155 , IEC 60268-3 , IEC 60335-2-2 , IEC 60335-2-7 , IEC 60335-2-14 , IEC 60974-1 , IEC 61000-2-2 , IEC 61000-4-7 , IEC 61000-3-4

ISO 31000	*Risk assessment management and techniques – Guidelines*
ISO 50006	Measuring Energy Performance
BS EN115-1: 2008+A1:	Guidelines for the safe operation of escalators and moving walks
BS7801: 2008+A1:	
ISO 9001	Quality management
ISO 50001	Energy performance and management systems.
ISO 14001	Standard for environmental managements systems (EMS)

This table is a convenient tool providing a list of the standards relevant to maintenance work that may be also used in any future research into the implementation of standards in this complex area of work. Having the list printed and attached to maintenance guidelines in the workplace would also be an essential tool for maintenance managers, enabling them to check whether their practices comply to standards without requiring them to sift through lengthy guides to standards, summarised in table 4.1. I cannot emphasize enough the importance of this table for the safety of ongoing work in maintenance departments and for enabling ongoing research into improving safety. Being able to check which safety standards should be included in work guidelines, simplifies the task of making sure that work guidelines match safety standards to the extent of making it feasible rather than overly cumbersome as in the past. Safety officers and maintenance managers should no longer be deterred from working according to safety standards, which should improve safety of maintenance departments. The next section describes the multi-grounded research carried out to assess maintenance workers' current familiarity with the standards included in the TOSSREM, the outcome of which underscores the great need for change.

4.3 Multi-grounded research stage: The Interviews Assessing Maintenance workers' familiarity with standards, and the implementation of standards in their work.

Having compiled the TOSSREM list of Standards the next step was to conduct interviews in maintenance departments assessing whether these standards were known to the personnel, whether they were understood by them and whether they were included in work guidelines and implemented in maintenance tasks. in maintenance departments. The evidence collected in this multi-grounded research would then allow me to I lead action research designed to move towards resolving the problem.

4.3.1 Selection of Research Participants.

The first criterion for an organization to participate in the research, was that they have their own maintenance department, whether it only included in-house employees or also outsourced personnel.

The next basic criterion was organizations who gave their consent to participate in the study, including individual consent from personnel. The customer portfolios I hold in my consultancy include significant amounts of background data from incident enquiries performed by the consultancy. This helped me select those organizations relevant to be contacted to ask permission to participate in the research. Each portfolio I held for each SME also includes the mandatory standards and standard families imposed on the organization's maintenance department. Some of the organizations are SMEs who make use of outsourced professionals and some are services that supply outsourcing to various organizations. For these reasons, outsourcing organizations were also included in the study, to highlight whether awareness of standards is a problem in these bodies.

Personnel from organizations selected for the study were asked whether they consented to be interviewed. The purpose of the interviews was explained as research related to comprehension of standards and their inclusion in work procedure guidelines.
The variety of SMEs initially approached to be included in the preliminary survey are shown in Table 4.3. All were partially or completely maintained by 16 outsourcing companies.

Table 4.3 –Maintenance Departments of Organizations originally considered for the study

Organization type	**Number of participants**	
	Local	**International**
Hotels	45	75
Office Buildings	55	
Small and medium-sized healthcare compounds	22	
Retirement residencies	22	
Shopping centres	3	
Luxury residential complex	1	
Outsourcing bodies	8	8
Total potential organizations	156	83

Initial questionnaires explaining the research and asked preliminary questions (see 4.3.2) were distributed to the pool of 239 organizations shown in table 4.3. However, personnel in many of the organizations which had agreed to participate in the study, became nervous about participating. Although complete anonymity was one of the conditions of the study, people

were concerned that admitting that the organization did not know of standard regulations or did not understand them, might be considered an inditement of the organization or of themselves. Even when the interviews were conducted, and questionnaires filled out, many were not fully completed.

At this point the criteria of the study were changed to only include Israeli organizations. From the total of 239 organizations only 156 were Israeli. After this, further organizations decided not to participate in the study leaving 76 potential organizations. After I discussed further criteria for the study with IBDO/MATI and the University, the number of participating organizations was further reduced. Finally, as shown in table 4.4, in the end, 60 organizations participated in the study.

Table 4.4. Organizations initially participating in the study

Organization type	**Numbers of organizations**
Hotels	34
Office Buildings	5
Small and medium-sized healthcare compounds	10
Retirement residences	3
Shopping centres	0
Luxury residential complex	1
Outsourcing companies	7 local companies belonging to two large service providing groups
Totals	60

4.3.2 Introducing the Study into Maintenance Departments

Initially preliminary meetings were held with maintenance department managers of the 60 organizations, in which permission was sought to start the research including in depth interviews which would be followed by coaching sessions. Unfortunately, at this point permission was not given by many organizations, and only 40 organizations agreed to participate. One concern may have been that employees felt they may be pointing a finger at their organizations if standards are not properly imposed. They may also have been reluctant to admit that standards were not understood, and therefore not followed. The assurances of

confidentiality and anonymity did not help. After discussions with managements of several organizations, I discovered that they were more willing to participate if I used the ideas of TQM (Arikkok, 2017; Pekar, 1995) which were familiar to the management professionals. Understanding that communication within and between departments was essential to the quality of the service offered, department managers became willing to co-operate with the study and allow department members to answer the questionnaires and take part in the surveys. In accordance with the one of the TQM ideas outlined by Naidu, Babu, & Rajendra, (2006) the surveys did not have to distinguish between personnel with different professions, as the same ideas applied across the board when trying to understand *why* standards were not implemented. If an instruction is not understood and not being followed, it does not matter what the instruction relates to. The key point was to focus on comprehension, and then on the inclusion of rephrased information in easily understood work guidelines.

After establishing the final list of participating organizations each one was categorized according to the specific maintenance parameters carried out by them. After that, documents were obtained from all of the procedural guidelines of the organizations in the various categories, together with documents from insurance investigations regarding the specific maintenance tasks performed by the organizations. These activities were crosschecked with the TOSSREM to ascertain which of the standards' sections and regulations should be included in the maintenance departments' guidelines, based on the type of work they perform, and on the environment in which it is carried out. Obviously, in cases where compulsory standards or parts of standards are described by local authorities and expected to be part of organizational procedures, they were also included in the interviews in addition to the standards included in the TOSSREM.

I then held introductory meetings in all of the participating organizations to present the research. I explained who I was, that I would give the interviews and how people could opt out anonymously, and indeed on the anonymity of the entire process. The number of interviewees participating in the research from each SME differs according to the number of workers in the maintenance department. The smallest group was five participants and the largest was fourteen. Each interview was conducted face to face, in a one-on-one format and was allocated 30 to 45 minutes. My intention was to eventually compile the results from the interview questionnaires into tables revealing which elements of standards' sections are not comprehended by personnel within the organizations.

It was decided by the organizations accompanying the research (firstly MATI and then the university) that all the questionnaires would be written in Hebrew, and all forms would be filled out in Hebrew, with this being the language in which the local interviews were conducted. All of the answers given during the interview were written in Hebrew, with this being the local language. I translated the answers from Hebrew to English together with other bilingual members of my consultancy firm, and the translations were validated by IBDO/MATI and stored on Excel type data bases in their computers until the organization closed. Unfortunately, some of the data was lost due to the MATI office closure, with only the data held by me forming the basis for this thesis. Most of the early material gathered, translated and computerized up to the end of 2017 was lost.

The questionnaires were categorized as to the different organizational environments in which the survey is conducted, however, the profile of the interviewees was nearly identical between the organizations. I conducted all of the interviews on site at the organization site. The interviews were intended to map out which of the Standards' sections from the Tables of Standards' Sections relevant to their professions (TOSSREM) the workers i) were familiar with ii) understood and iii) put into practice. Team leaders and other workers in organizational maintenance departments, should be familiar with the details formulated in the various relevant standards. They should understand them and comply with them in their work. The "team leaders", were noted in the questionnaires, with this referring to those employees of the organizational maintenance department who head a team, without definition or separation either in terms of rank or affiliation in a specific department or profession.

The interviews needed to differentiate between cases where maintenance workers knew that they were directed to use particular materials or methods designated in the standards, but ended up using incorrect methodologies or materials; and cases where the standards were unknown or misunderstood. The aim was to determine precisely what was being misunderstood, and what, if anything, was clear to these workers. It is important to note again, that this study does not address economic phenomena such as lack of manpower or lack of proper equipment and tools for carrying out the work. When it became clear that the main problem related to comprehension of the standards, the interview questions were adapted to assess the extent of understanding of and compliance with these standards.

After the initial rounds of interviews, it became evident that comprehension of standards was an important issue. I repeated the interviews and coded the answers to each of the questions in relation to each group of standards as follows: i = Standards are not known and so not implemented; ii = management is familiar with the standards but considers them too complicated to be implemented and iii = standards are understood and implemented (see section 4.3.7). The distribution of the answers to the questions asked are presented in chapter 5 on the research findings.

4.3.3 My dual role as a consultant and action research practitioner – ethical approval

As explained in Chapter 1, my position as a consultant to professionals working in a wide range of SME maintenance departments presented many advantages for planning the research. The participants in the research all belonged to organizations with whom I held consultancy contracts. Thus, contacts with the maintenance departments already existed, and I was familiar with many of the personnel. Furthermore, I was deeply familiar with many of the tasks conducted within the maintenance departments. The one concern raised when planning the research was the possibility of personality clashes and reticence to share sensitive information with a consultant who may pass on the information. However, as the interviews were conducted under conditions of anonymity this problem was resolved. Another potential problem was that management may misinterpret the research as an attempt by me or any other researcher to "impose" standards on the maintenance departments.

As with all research involving people, the research proposal was submitted to the ethics committee and approved. During the preparation of the research the issue of my involvement as the researcher and as a regular consultant to the organizations was considered, and approved. This was borne out as my presence on the sites was gradually seen as potentially advantageous to the SMEs when they realized that the action research could resolve actual problems on the ground in their maintenance department. Furthermore, interviewees were allowed to refuse to be interviewed without my knowing about the refusal, with this preventing any problems of personality clashes.

The potential problem of a researcher being seen as "imposing" standards or components of standards on the maintenance departments was never really an issue. Standards are "imposed" on maintenance departments by insurance companies and by local and national authorities supervising maintenance work. I was able to explain my role as facilitating a total quality management approach including the explanation of regulations which were often not

understood. My role as a researcher in supplying operational methods enabling the inclusion of rephrased and explained standards in work procedure guidelines was eventually understood and appreciated. In fact, SME managements began to understand that not having the kind of coaching sessions that I was offering is the reason for SMEs ignoring critically important safety standards. It was as if not understanding the standards released them from their obligation to follow them. Furthermore, once it was explained that no restricted information divulged during interviews would appear in the research findings most obstacles to starting the research were removed and the action research process could begin.

4.3.4 Preparing interview questions and conducting preliminary interviews

a. Preliminary interviews for personnel from the selected organization before the on-site interview.

The purpose of the preliminary interviews was for me to gain an overall understanding of the organization. The questionnaire enabled interviews to be standardized. This later helped with grouping of similar organizations together. The interview questions are included in annex 1. These interviews were intended to create a rich picture of work processes in maintenance departments. Answers were recorded for each department.

4.3.5 Refinement of interview questions

During the first few interviews conducted it became evident that the work guidelines used in maintenance departments defining how particular tasks should be carried out, often did not match directives in standards for the same task. This needed to be addressed before continuing with the interview process. Furthermore, there could be differences between sets of guidelines for one particular task in different parts of one organization.

Being an enthusiastic fan of Argyris & Schön writings, as soon as I found these contradictions and incompatibilities, I began searching the literature, convinced that I was not the first one confronted with this kind of issue. Based on concepts of social learning and the double loop learning, found in the literature (Argyris & Schön, 1978; Argyris, Putnam & McLain Smith, 1985), I improved the interview process by inserting appropriate questions that would highlight the contradictions and incompatibilities between the regulations and the

work guidelines, instead of avoiding them. In brief, I accepted that in order for learning to take place it was necessary for personnel to understand why changes needed to be made, and not simply which changes needed to be made.

I then restarted the interview process. This process revealed that the interviewees were aware of contradictions and incompatibilities, between standards and their work guidelines but that this prompted them to ignore the standards. However, throughout the process it was important to maintain the main goal of the study in view. This was to generate a work procedure guideline that cover the necessary components included in standards and regulations.

4.3.6 Analysis of the data and the Incorporation of Fuzzy Logic

After I finished conducting the interviews, which included asking the questions outlined in chapter 5, while presenting the specific standards components related to maintenance work included in the TOSSREM, I then had to devise a methodology to categorize the answers I received. In many cases the answers were initially ambiguous and hard to categorize, as for example the maintenance professional may have been aware of the existence of the particular standard, and may have been slightly familiar with it, but did not understand it. On the other hand, the interviewee may have been fully aware of the particular standard and may also have fully understood it, but for various reasons did not put it into practice. I had to be careful about the way in which the questions were asked and the answers recorded. The aim was to categorize the interviewees' answers as to how familiar each interviewee was with the information in the standard asked about; to what extent this information was understood and to what extent it was put into practice. The answers then required a suitable tabulation method.

Early on in my training as an engineer I had attended lectures by Lofti Zadeh on fuzzy logic. His ideas on fuzzy mathematics and fuzzy logic, that an individual answer to a question may have varying degrees of truth and therefore be given a value anywhere between 0 and 1 rather than just either 0 or 1, were integral to my research design based on interviews and open-ended questionnaires. A simple fuzzy logic system of encoding values with a verbal description is given in Dwinnell (2002). I was collecting verbal answers and not numeric data, and fuzzy logic (Zadeh, 1965), allows treatment of variables that are linguistic rather than numeric (Zadeh, 1975a,b). That is to say, each possibility has a description written in

words, rather than being given a single numerical value. These linguistic values have 'fuzzy edges', meaning that the borders are not clearly defined, and the values may overlap with each other (Zadeh, 1975a,b) so a finding can belong to more than one set (Klir & Yuan, 1995). In this way, fuzzy logic allows a researcher to deal with uncertainty, which is useful in many real-life situations where information may be vague (Singh et al., 2013; Zadeh, 1975a,b). This is generally the case in complex situations. Fuzzy logic has been widely used in studying safety and risk assessment (Bowles and Pelaez, 1995; Li et al., 2010; Markowski et al., 2009; Yadav et al., 2003).

In this study fuzzy logic was useful for interpreting the answers given to open ended interview questions, where the information given may not fit precisely into any particular field. This was particularly helpful as it allowed an individual asked about familiarity with a particular safety standard, or used it during day-to-day activities to reply 'to some degree' rather than just yes or no. Answers which were considered equivalent to 'no' could be entered into column i, answers which were considered equivalent to 'maybe' or 'to some extent' could be entered into column ii while answers which were considered equivalent to 'yes', could be entered into column iii. In this way, the interviewee's answers which had been noted alongside each question, were sorted into the category of answers which matched the interviewee's answer most closely. This was done for each question in each questionnaire. The categories were validated by a team of three (see section 4.3.7).

The questions asked are shown in the results sections from tables 5.2 – 5.12. The answers given by each interviewee were noted and recorded in relation to their place of work. I asked open-ended questions in order to gain the fullest possible picture of what was taking place in the maintenance departments. The principles of SSM, grounded research and CIT were all taken into consideration when I asked the questions. The aim of the questions was clearly defined, the qualitative data was collected in such a way that it could be coded afterwards, with an emphasis maintained on the human and social aspects of the organization.

4.3.7 Validation and Tabulation of Results

The category to which each answer was allocated validated by a team of three which included myself and two members of the IBDO/MATI organization which accompanied the research, both of whom were human resources professionals. The original transcripts of the interviews including my personal notes were submitted to the two professional Human Resources consultants working at the IBDO/MATI who assessed the interview transcripts and results. Only when the answers given by interviewees were assessed in the same way by all three

team members were the interviews included in the study. This reduced the number of interview answers included in the study, but it was deemed necessary that all three adjudicators must reach the same conclusion about the answers for the interview to be validated and included in the study. The answers were tabulated in three columns (as explained above in section 4.3.6): column i) Standards are not known and so not implemented; column ii) management is familiar with the standards but considers them too complicated to be implemented and iii) standards are understood and implemented (see chapter 5). This qualitative tabulation enabled me to extrapolate the required information in order to build each of the coaching sessions appropriately for each organization, with regard to which elements of the standards were not fully understood.

4.3.8 Writing supplementary material

After compiling the TOSSREM tables, and conducting the first round of interviews, an in-depth examination of the standards revealed that most of them are worded in such a way that meet the requirements of highly qualified professionals, who need to include them in their work procedures and present them to others, both in terms of their formulation and in terms of their content. However, their complexity serves as a deterrent to their use by those maintenance workers who are supposed to be guided by these standards, but do not have the training enabling them to interpret the obtuse wording and highly technical jargon. As indicated by Campbell, (1995), Holmgren, (2006) and Jackson et al., (2001) there is often inadequate communications between maintenance workers and central management, and insufficient training spaced apart at long intervals, leaving workers with no one to fall back on when technical language is misunderstood (Mwanza & Mbohwa, 2017; Zakiyoudin et al., 2014). This lack of communications and lack of comprehension results in these personnel 'rejecting' the standards and ignoring their existence.

The way forward seemed to lie in the incorporation of the relevant information from the standards into easily understandable work guidelines, to be distributed to and used by all maintenance departments. The guidelines would be aimed at the three groups of standards: increasing safety, making more efficient use of energy and protecting and preserving the environment. Based on the information obtained during the interviews and coaching sessions, explanations were written about the contents of Standards which had not been clearly understood.

Supplementary material was offered to the interviewees containing the TOSSREM table of standards derived from the survey conducted in the first phase of the study, together with explanations of those standards. However, after the first round of interviews, I realized that none of the interviewees had fully understood the standards. More explanatory information was needed, written in a way that was easy to understand. During and after coaching sessions this supplementary material was refined, until it served its purpose adequately well.

4.4 COMTRAP TABLES

After the interviews were completed with regard to the standards included in the TOSSREM tables, further tables were collated which included including all the sections of standards which had not been understood or had not been complied with. These tables can be referred to as 'Compliance with Standards for the relevant profession" or COMTRAP tables. These included regulations which had not been properly understood by maintenance workers in a particular organization and therefore were not used by the organization. These tables were then used to prepare material which would be used in the action research part of thestudy during coaching sessions and in preparing explanatory material about the standards, which would be used in further interviews.

4.5 Action Research Stage: Coaching sessions

4.5.1 Organizing material for coaching sessions and refining supplementary material

It was clear, that in order for the research to yield the goals of improving comprehension and implementation of standards in the field, the strategy had to include not only collecting data but also generating a new transformative approach. The Action Research based on interactive coaching sessions would not only help further clarify the problems being faced but also contribute to introducing a solution by producing guidelines for safe and effective practice (Denscombe 2010, p.6). It was also clear that not only the research itself had to be undertaken within maintenance departments, but also the actions resulting from the research must, inevitably, be managed within the maintenance departments themselves, for long-term change to be achieved.

For this to be put into practice, I had to adopt four basic themes of action research: empowerment of participants, collaboration through participation, acquisition of knowledge, and social change (Greenwood & Levin, 2007; Hult & Lenung, 1980; Koshy et al., 2011). These may be attained through five phases of inquiry: identification of the problem, collection, and organization of data, interpretation of data, action based on the data and reflection (Ferrance, 2000; Montgomery et al., 2015).

Each session of interviews was conducted in-situ at the sites where the maintenance organization was based. The analysis of the interviews revealed which sections of the standards were not properly understood in each organization. Those standards categorized in COMTRAP tables as not being properly understood by maintenance personnel were explained to the workforce in coaching sessions. The first stage however, before commencing the coaching sessions was to rephrase the material in these sections of the standards so they could be easily understood by everyone having to work with them.

When rephrasing the standards, I included citations from the standards expressed in simple language. These short explanations could then be included in work guidelines. The explanations also included references to the complete standards, so I was respecting the ruling that all quotations of standards have to include a referral to the published standard. This was done for each and every standard that I worked with in the interviews and coaching sessions. The choice of information included in the explanations was guided by the analytic hierarchy process (AHP) of decision making as described by Saaty (2012). AHP simplifies multicriteria decision when the data is discrete or continuous, with feedback throughout the process. This allows several factors to be considered simultaneously, when using a hierarchy to represent the relationships between the various elements.

The aim of the interactive coaching sessions was to ensure that the rephrased material selected through AHP was fully understood. The explanations could then be included in work procedures. Once it became apparent that the wording was understood by the group of professionals who needed to comply with the information extracted from the particular standard, clear procedural guidelines were drawn up which could be understood by the workforce. These directions were intended to include all of the important information from the standards so that correct materials and methods could be followed from the start of each project.

The issue of generating the audience's interest in the coaching session was one of the cores issues the action research. The management of many of the SMEs described one of the reasons behind the failure of past training programs had been lack of interest from the audience, as the material presented had not been relevant to their experience and to the projects they were involved with. It was critical to tabulate precisely which parts of the standards were not understood, for the coaching sessions to be relevant, interesting and to serve their purpose of getting personnel on board with promoting the inclusion of standards in work guidelines.

The coaching sessions were based on the principle that change constantly occurs within organisations, and training or coaching can help individuals lead that change. The goal of the coaching was to help all of the participants become confident in using the standards, helped by the explanations provided. Furthermore, the coaching sessions conveyed the importance of implementation of standards in maintenance work, with this being brought about by including clearly worded information from standards in work guidelines.

Various questions were considered in planning this stage. One question asked was whether this research could cover all standards required in maintenance departments, with all of the relevant information from the standards then included in one single guide which would be explained in one type of coaching procedures. This would be a type of 'one size fits all' procedure. The alternative would be for the guidelines and coaching sessions to be divided according to specific subjects or issues or according to specific types of organizations. The findings from the interviews conducted on site, in the different types of organizations, presented a surprising uniformity in which standards were needed regardless of the type of organization. The findings also showed a similar lack of understanding of standards at all different types of organization, enabling the research to cover all participating organizations.

I decided that the ultimate aim of the action research would be for all of the relevant information from the standards to be included in one single guide which would be explained in one type of coaching procedures, in a way that was interesting to the participants and easily understood by them.

These topics could then be addressed in coaching sessions, including role play of the different situations arising from not understanding directions included in standards. These role plays are key to keeping the audience interested and also key to ensuring that participants fully understand the material being covered. For example, all maintenance departments are required to comply with the American NFPA 72 Standard. This standard is called “the bible” of fire alarm systems by professionals. The fact that this is an American Standard has given rise two main issues: firstly, organizations functioning according to European standards were not aware that they have to refer to this American standard; and secondly the standard is formulated with American units of measurements rather than metric units (e.g. inches rather than millimetres) and using American professional technical jargon, which is usually different from the one known and in use locally.

These two issues have led to fire detection equipment, fire alarms and other fire protection systems being incorrectly installed resulting in lack of protection. In a private health centre, supplying dialysis services, a malfunction of the fire protection system triggered by a patient secretly smoking a cigarette, resulted in all the dialysis machines stopping working. The machines went into the cleaning process cycle, which normally runs at the end of the work day, while still connected to patients. This caused tremendous suffering and the deaths of two patients. The accident investigation revealed that the fire protection system was improperly installed and maintained. The system should have been programmed according to occupancy level. Furthermore, while the system was in use treating patients, no change of procedure should be started as long as no staff intervention was recognized by the system.

One of the Standards relevant to this medical centre is - IEC 60601.1.2 “Medical electrical equipment – Part 1-2: General requirements for basic safety and essential performance”. The Standard specifies extreme situations: “failure of automatic diagnosis or treatment EQUIPMENT and SYSTEMS to diagnose or treat, even if accompanied by an alarm” indicating proper functioning for these cases. But studying and understanding this standard shows that its specifications include contradictions with NFPA 72 requirements. To put this more accurately, the Standard includes specifications as to how to overcome these issues. But as the Standard was not properly understood two patients died and 23 others suffered terribly. This situation exists in many centres supplying Dialysis services, as they are installed in many different locations such as hotels, commercial centres, office buildings and more. These locations requiring adaptation to give this type of services, but they are unaware of these

demands. For these reasons preliminary interviews were conducted in this research to properly understand each organization's needs on each particular site. During role plays, workers could describe situations when they had come across these kinds of circumstances, when they had not realized that standards were using different units to the units they were familiar with. They also could relate to not knowing that standards composed in different countries were relevant to the work they were doing. After becoming aware of these issues workers were able to explain the lessons learned through this experience to other workers. The workers who participated in role plays in the coaching sessions could also use the techniques they learnt as models for helping explain complex material to others.

In another example, some aspects of safety at work had been receiving attention in the media at the time the research was undertaken. In some of the incidents covered, the lack of personal protective equipment had resulted in severe injuries or fatalities. This was one area that the interviews and coaching sessions focussed on. A personal protective equipment (PPE) survey was conducted as part of the interviews. It should be clear to anyone who examines a work procedure that, in the event that a job is carried out high above the ground, or is specifically described as being carried out in highly risky areas, then the worker must possess the necessary skills and wear personal protection while carrying out that job. Safety equipment such as hard hats, safety tested harnesses, platforms, scaffolding, lifts and pulleys all must be used when appropriate. This is regardless of the specific profession of the workers and the nature of the work performed. Standards and work safety regulations define job performance scenarios that require protective equipment and personal protective measures while emphasizing the work environment. It is clear that the additional safety equipment specified in the standards and regulations relating to work at heights is additional to the equipment required for carrying out the defined professional work. The safety specifications must be listed and added to the work procedure documents.

Personnel could easily relate to this example in coaching sessions. Standards include precise lists of the additional pieces of equipment and work tools required to perform particular tasks. These tools and pieces of equipment are intended to be on site and in-use in each and every set of tasks specifically described in procedural regulations. If the tools are not on-site, then the work cannot meet the standards' requirements. Talking about this common experience with maintenance personnel could also empower the professionals by enhancing their understanding of why standards need to be followed. The definitions of tools and materials

are also used during inspections assessing that all materials and tools required for those jobs are present in the organization's inventory and are working properly and match specifications. It is essential that team leaders are familiar with these lists. Once more, when personnel understand why this is essential, they become active participants in the process, and promote the implementation of standards.

Another area the research focussed on was environmental protection standards. Specific standards apply to sites are defined as being hazardous, with highly flammable materials or explosives, which present a high risk of causing environmental pollution. However, standards also cover sites that may be sensitive to environmental pollution, with these also dealt with in specially designated sections. An emphasis is placed on the protection of internal environment from pollution to the site. Precautions are also defined where sites may cause external environmental pollution as a result of the work being done.

The environmental protection standards that are most relevant to organizational maintenance departments include: treatment and disposal of waste; effluent disposal; energy control; chemical disposal and maintaining energy efficiency at all times. With burgeoning numbers of standard regulations, some inconsistencies have developed. The conflicting directions given in different standards have led to accidents and other problematic events. For example, one of the guidelines for environmental protection was a recommendation made to reduce the flow of swimming pool water containing a large amount of chlorine to the sewage. This had been instituted since chlorine can cause severe corrosion and damage to metal sewage pipes. This directive, although completely correct with regard to metal sewage pipes, is not relevant at all to the other types of plumbing, such as plastic pipes. This is a significant issue when the chlorine is used in out-door public and private pools, as chlorine evaporates at high speeds and therefore the level of damage it can cause is low (or non-existent). For many years now, plastic or concrete pipes are used, not steel ones as in the past, and chlorine does not interfere with these types of pipes. As in this case, problems can be caused by correctly applying an old standard, that is not up to date. This added a challenge to the research, as it was not only important that standards are understood and implemented, but it was also important that the correct, most up to date standard was fully understood and was being properly implemented.

A further example relates to the disposal of fats, oils, grease and food waste in institutions' kitchens. It is important to prevent oils and grease from entering the sewage pipes which are easily blocked by fat deposits. These fats also cause environmental problems if they reach

streams and rivers, causing water pollution. Fats and oils congeal as they cool, sticking to the inner lining of pipes. Using detergents or bleach may appear to wash the fats away, but in fact, it is not a solution. The detergents cause a more serious problem, increasing the numbers of pollutants in the water. Moreover, the fat/detergent mix solidifies further on down the pipes causing more serious blockages. Therefore, in addition to separating food waste from all items to be washed, all fats must be wiped away too, and diverted to grease traps. Grease traps are supposed to be built into the plumbing of institutional kitchens. Grease builds up in the traps, and is periodically safely collected and disposed of. However, grease traps are only effective if they are correctly installed and maintained. The ministry of Health has written directives concerning the installation and maintenance of the traps and collection of fats from every installation with an institutional kitchen.

However, guidelines given to the commercial companies supplying the traps did not relate to the size and type of kitchen, the size of the pipes and drains and the volume and type of waste being dealt with. As a result, in many kitchen unsuitable traps were fitted, which did not handle the fatty waste effectively. If the traps were too large, then the fats were not trapped effectively, with too much water being retained, resulting in high volumes being sent to the treatment centres at high costs. The organizations therefore quickly developed reasons not to use the traps. This was only discovered during investigations into instances of high levels of pollutants in waste disposal units, events which caused serious environmental damage including risking loss of life of both animals and humans in the vicinity of these treatment centres.

Standards relating to risk assessment are also applicable to all maintenance departments. An example of problems occurring when risk assessment standards are not understood and put into practice occurred at a public event. The event centred on a number of performances, and a stage was built for artists to sing and dance on. When the risk survey was undertaken, they only considered the variables which the person conducting the survey knew about. The parameters of electricity and stability of the stage were given serious consideration. However, nobody took into account that there may be sudden changes in the weather, including strong gusts of wind. On the evening of the performance, the strong winds knocked the amplifying sound system into the front rows of the audience. In the parameters defined in risk surveys for events of this kind, it states that the person conducting the risk assessment survey must check weather forecasts. Furthermore, they specify that the possibility of strong gusts of winds, which require all lighting and sound systems to be adequately secured, must be taken

into account. Once again, this demonstrates the importance of standards being fully implemented in work guidelines. When asking about risk assessment, the study had to make sure that all aspects of risk assessment surveys were fully understood.

4.5.2 Repeating Interviews.

A second round of interviews was planned aimed in evaluating the level of improvement obtained in the comprehension of the standards, and was very positive as per obtained responses. The rephrased material designed to make it easier for personnel to understand the information included in standards was gradually adapted after it was tested in the coaching sessions.

These sessions were designed to follow the principles of action research, by actively involving the research participants in the continuing research process. Responses from the participants dictated the content of coaching sessions, and the rephrasing of information included in standards. The wording of explanations to be included in the work guidelines was repeatedly 'fine-tuned' until the content was fully comprehended. The continuing action study is intended to assess whether these new work guidelines, including information from standards in comprehensible language, contribute to improved safety performance, energy efficiency and environmental protection.

Following the conclusion of coaching sessions and repeated on-site interviews, I conducted interviews with the management personnel in all of the participating organizations. These interviews were aimed at ascertaining the general manager's level of satisfaction. During this process, the general managers were informed of the corrections already added to the organizational work procedures and how they are influencing and improving the safety in their organizations. During these interviews, the managers remarked about the subjects dealt during the coaching sessions. They also gave suggestions of how to insert the necessary additional components from Standards into the organizations' work procedure documents. All the participating organizations expressed their will to continue their participation in the next steps of the research at regular time intervals. As new incidents occur, and new investigation reports are written the action research needs to continue. Unfortunately, however, at present, all continuing processes are on hold due to the covid-19 pandemic and the resulting lockdowns and restrictions.

Chapter 5 – Research Findings

5.1 Findings from the interviews

5.1.1 Research participants

As described in section 4.3.1 initially a pool of 239 organizations were approached to participate in the study but, after filtering, 163 organizations were found not to meet the research criteria. Of the remaining 76 organizations, 16 decided not to participate after initially giving their consent. This left 60 organizations, including hotels, office buildings, health-care centres, retirement residences, a luxury residential complex and outsourcing companies, all with their own maintenance departments. Interviews were carried out in these organizations as shown in table 5.1

Table 5.1 Questionnaires completed in different types of organizations

Organization type	**Numbers of organizations participating**	**Numbers of completed interviews**
Hotels	34	111
Office Buildings	5	21
Healthcare compounds	10	33
Retirement residences	3	18
Luxury residential complex	1	6
Outsourcing bodies	7	6
Total numbers	60	195

5.1.2 Examples of Questions and Answers from Interviews

<u>Samples of questions and answers in a facility participating in the research</u>

The interviewee is one of the team leaders of the maintenance team.

After completing the preliminary part of the interview, the second part of the interview concentrated on questions about the standards which the interviewee had stated were not fully

comprehended. These questions are representative of questions presented to interviewees in all organizations participating in the research.

Question 1: According to published standards some of the work taking place on your premises requires two workers to work together during execution of particular tasks. When you are required to carry out these types of tasks, what usually happens? Can you describe incidents when you have been informed in advance that two people are supposed to work together on these tasks? Can you describe incidents when you were expected to know this by yourself? Have you been allocated partners for these jobs or did you have to find someone to work with? Can you describe what happened in cases when the task was declared to be urgent? Were you expected to carry out urgent tasks alone when there was no-one available to be appointed as partner?

Answer: In most cases we know which tasks require two workers from previous experience, however we only actually work in pairs occasionally in special circumstances where the work cannot be carried out by one person. We are not usually aware of particular standard regulations about this and we usually carry out most tasks alone. When the task is specified as urgent (most of the cases are outside of the regular work hours), usually the duty personnel try to solve the problem in the best possible way.

Question 2: In your work have you been required to replace accessory devices? Were you aware of standards which apply to these jobs? Were you aware of any specific safety procedures which apply to the jobs? Are you generally informed in advance about safety specifications or are you expected to know them by yourself? Are safety briefings carried out before you begin a task including the replacement of an accessory device?

Answer: We usually are given only a general briefing before replacing accessory devices stating that that we have to be alert to the specific requirements and to be careful. As most tasks repeat themselves, we usually are aware of the risks associated with a particular device and with replacing devices in general, and from our experience we know how to be careful. We are very rarely briefed regarding standards, essentially as most of our co-workers do not understand (like us) the specific standards. So, the execution of these tasks is carried out according to our understanding of the best procedures without taking standards into account.

Question 3: You have stated that part of your job involves receiving deliveries of specific devices. Can you describe what happens when such a delivery is due? Can you recall occasions when you have been informed about the type of device which will be delivered? Were you informed about the complexity of the device? Were you told to check specifics covered by standards included in the description of the device? If the device is covered by specific standards, are they presented and explained to you?

Answer: As previously explained, most of our colleagues do not understand the wording of the standards, or at best may partially comprehended some of what is written in standards. This means that most of us are ignorant as to what is contained in the standards for receiving special deliveries and, indeed, for any other standards. In certain cases where there are specifics that we need to be aware of, the supplying company sends instructions or sends a professional to supervise the task, but this does not happen often.

Question 4: Before beginning a task are you given work procedures outlining the stages of the task to be completed? Can you recall incidents when you did not understand parts of the work procedure as it was given to you? Did you ask for explanations about these? Can you recall incidents when these work procedure documents included information described as standards? Were there occasions when you did not understand the information included in the standards? Did you ask for clarifications on these occasions? Is it considered to be legitimate to ask for explanations? Would the management regard asking for clarifications to show a lack of professionalism? Would people asking for explanations be helped by management or would they be reprehended by management?

The answers to these questions depend upon the supervisor/manager or team leader we are working with. Often, there is no point asking questions as the supervisor/manager or team leader has no more knowledge about the standards than we have, so asking questions may just lead to embarrassing situations. This could lead to risky situations for workers. There is therefore no clear-cut answer to whether it is legitimate to ask questions or not.

The following tables 5.2 and 5.3 include examples of answers given by personnel to the general questions on standards which were shown in tables 4.5 and 4.6. The distribution of

answers amongst all the interviewees to all of the questions asked are shown in tables 5.4 - 5.13 that follow below.

Table 5.2 Examples of answers to questions about different type of standards. The example is from one interview, but it was chosen as being representative of many interviews.

Type of standards	Questions	Answer
Professional standards	1.Are these standards included in daily work procedural guidelines?	In most cases they are mentioned by their number or name but no more details are given.
	2. Are instructions including the standards given, along with explanations in training sessions in the organization?	In most cases not at all or in a minimal way.
	3. Is the implementation of these standards supervised by appropriately qualified personnel?	No
	4. Are corrective measures taken after failures are detected related to these standards?	Only if they are imposed by management.
Energy Efficiency and environmental protection standards	1. Are these standards included in daily work procedural guidelines?	Only if management intervenes and ensures they are added.
	2. Are instructions including the standards given, along with explanations in training sessions in the organization?	Only if regulatory bodies demand that these training sessions including standards are given.
	3. Is the implementation of these standards supervised by appropriately qualified personnel?	Only if regulatory bodies demand such supervision by qualified personnel.
	4. Are corrective measures taken after failures are detected related to these standards?	Only if regulatory demands impose it.
Risk Assessment Standards	1. Are these standards included in daily work procedural guidelines?	Only if regulatory demands impose it.
	2. Are instructions including the standards given, along with explanations in training sessions in the organization?	Only if regulatory demands impose it.
	3. Is the implementation of these standards supervised by appropriately qualified personnel?	Only if regulatory demands impose it.
	4. Are corrective measures taken after failures are detected related to these standards?	Only if regulatory demands impose it.

Table 5.3 shows examples of answers to questions about different type of standards. The example is from one interview, but it was chosen as being representative of many interviews.

Table 5.3 Examples of answers to questions relating to imposition of standards and selection of personnel.in table 4.6.

Q.		Answer
	Topics relating to regulations in use in the organization, from the perspective of personnel	
1	IEEE & IEC standards are in use, together with local regulations.	No specific knowledge.
2	Only those imposed by authorities and verified regulations are used.	In most cases.
3	Only insurance requirements are imposed.	No specific knowledge.
4	Organizational procedures are used.	Yes
5	Prerequisite certifications and accreditations are verified.	Occasionally
6	Known and recommended workers are selected.	Occasionally
7	Occasional personnel are used.	Occasionally
8	Personnel are used depending upon availability.	In most cases
9	Management supplied personnel are used.	Occasionally
10	No departmental personnel descriptions are imposed.	This depends on management decisions.

In answer to questions on how well safety standards, environmental protection and energy efficiency standards and risk assessment standards were understood, all answers were: “They are partially understood”. Likewise, the answers to almost all questions on familiarity with standards, record keeping, deficiencies in record keeping and the applications of standards of all kinds of jobs were also defined as “partially”. The distribution of answers amongst all of the interviewees are shown below in table 5.7

5.1.3 The main finding from the interviews: Lack of familiarity with standards and lack of comprehension of the wording of standards.

The main finding from the interviews was the surprising extent of maintenance personnel's ignorance about standards. Even in cases where maintenance professionals had heard of a standard, many did not understand exactly how they were supposed to follow the regulations included in the standard in practice. This situation meant that the action research planned in the form of interactive coaching sessions could not only focus on informing personnel of relevant standards, but must also address the issue of comprehension of standards. This became an integral part of the coaching sessions in stage three of the research, which had not been planned from the beginning. Part of the problem was the complex language of the standards, which are filled with technical terms. However, other problems exist too, which create challenges when trying to follow standards. Many of the standards appear in one place in a standards' guide, but refer to other parts of the guide. In order to work according to these instructions a maintenance worker must have access to all the scattered sections of the standard. The workers must also have the versions appropriate for the equipment they are using. Whether the language and wording of the Standards was understood or not is a different topic to whether the technical content of the Standard is understood. The interviews needed to ascertain whether the wording of the Standards- the language used – was understood and could be put into practice.

It was also surprising to discover that there was no correlation between the education of interviewees and their comprehension of essential standards. This was supported by the finding from 38 interviews carried out with engineers in the same organization (electrical, mechanical and chemical engineers). There were similar levels of miscomprehension or inability to implement the standards amongst engineers as amongst interviewees with lower levels of education. Two prominent examples were that chemical engineers did not understand the standards for checking the composition and ionic concentrations of elements in hotel water systems and that electrical engineers did not know the purpose of many standards for installing electrical distribution panels before operating them.

5.1.4 Work guide lines do not match standards.

One of the overall aims of the research was to ensure that correct information from standards can be included in maintenance department guidelines. Interviews revealed that there was a lack of compatibility between many of the standards included in the study, and the work

guidelines used on a daily basis in maintenance departments. A simple example was found when looking at regulations instructing how to maintain and sterilize hot water reservoirs and the prohibition of use of some types of chemicals. These contradictions and incompatibilities became prominently noticeable immediately during the first interviews. This was a serious impediment to the continuation of the process.

During the interviews, as noted in section 4.3.5 I also found that different sections within a single organization sometimes created different, and possibly conflicting, work guidelines. These also often included incorrect instructions or definitions that were inconsistent with the fulfilment of specific standards' requirements. One solution to this problem was to formulate informative and up to date work guidelines documents including clearly worded relevant Standards. The grounded research stage of the study conducted through interviews helped identify which standards needed to be incorporated in these guidelines, which ideally would include all of the necessary components for maintaining the organizational environment, in compliance with the existing regulations and directives. This should enable smooth and continual functioning of the organizational maintenance departments, while preventing unnecessary accidents. The guidelines should comply with existing standards. These guidelines should help maintain high quality performance in maintenance departments.

5.1.5 Areas of the selected Standards rephrased to enhance understanding

Each time a term was encountered in the Standards, that required "rephrasing" into simple language, the research had to stop until a solution was found. Each attempt of 'rephrasing' the information found in the standards was tested with maintenance professionals, to find out whether the attempt had been successful. Later on, it was possible to include the rephrased parts of the standards in the third part of the study. In this third phase which consisted of interactive coaching sessions, when explanations of rephrased material were offered to maintenance personnel, the interactive process allowed more suggestions to be considered. This cut down the time involved, as we could assess 'on the spot' whether rephrased language was well understood. Gradually a table of equivalent terms was put together that could be used in further coaching sessions.

Various themes emerged in the interviews which were later highlighted as reoccurring in many different interviews. The topics highlighted in the preliminary interviews were listed to serve as material to be used in the interactive coaching sessions.

5.2 Analysis of the interview findings

As there were different types of organizations participating in the research, and maintenance personnel with different professions answered the questions, a wide variety of standards found in the TOSSREM table were used in the research. Notes were written at the conclusion of each interview, including the answers given to the questions, which could be coded as explained in section 4.4. The collected data from the individual interviews on all of the different sites needed to be validated, tabulated and analysed before the findings could be discussed more conclusively and used as a basis for interactive coaching sessions and for the composition of new work guidelines as discussed above in section 5.1.4 and 5.1.5. From the beginning of the interviews process, it was clear to me that a tabulating system for the results that would help enable the process of analysis needed to be found.

5.2.1 Validation of and tabulation of results

The findings were validated and tabulated as described in section 4.3.6 and 4.3.7. As explained in section 4.3.6 I decided to use concepts from fuzzy logic in sorting and presenting the results. The verbal answers given to the open-ended interview questions could be viewed as linguistic variables (Zadeh, 1975a, b), with complex answers, not a simple ‘yes’ or ‘no’. The answers were divided into three different categories with ‘fuzzy edges’, as described in section 4.3.6, so an answer could be considered to belong in different categories (Klir & Yuan, 1995). The first set (i) would include all answers that indicated that the interviewee was not aware of the existence of a standard on this subject. The second set (ii) would include a wide variation of answers that indicated that the interviewee did know that a standard existed, but also felt that the standard was written in a way that was too complicated to be understood. For this reason, the standard was ignored. If the interviewee was responsible for writing work procedural guidelines, this also meant that the information from the standard or guidance would not be detailed in the organizational work procedure. For other interviewees, who were following work guidelines, it could mean that the information was not included in these guidelines. The end result is that the important information in the

standard is ignored. The third set (iii) would include all answers that indicated the interviewee knew about the standards, that it is included in the guidelines for work procedures, and followed by maintenance workers in the organization. While a certain degree of uncertainty remains, fuzzy logic accepts that this uncertainty characterizes real-life situations, where information may be vague (Singh et al., 2013). In this study this is appropriate for interpreting the answers given to open interview questions, where the information given may not fit precisely into any particular field.

I sorted the answers into three groups, i, ii, and iii. Answers which were considered equivalent to 'no' were entered into column i, answers which were considered equivalent to 'maybe' or 'to some extent' were entered into column ii, while answers which were considered equivalent to 'yes', were entered into column iii. The distribution of the answers into these sets for each question is presented in tables 5.4 – 5.12. This tabulation allowed me to rapidly form a general impression on interviewees' familiarity and understanding of standards. The distribution of the answers throughout the interviews clearly demonstrated that there was an overwhelming lack of knowledge and comprehension of standards. The themes arising from the full answers to interview questions are presented in section 5.4. The qualitative aspects of the interviews which followed principles of grounded research and CIT add depth to the picture gained by the depiction of the distribution of the results in table form.

Tables 5.4 -5.12 represent the interviewees' answers to questions on how they view the operation of the maintenance department they work in. The answers are shown distributed between the three sets i, ii, and iii.

5.3 Distribution of Interview Results

Tables 5.4 – 5.13 present the distribution of the answers to interview questions into three sets as explained above in section 5.4.3.

5.3.1 Results of General Interviews

Table 5.4 represents the interviewees' answers to questions on how they view the operation of the maintenance department they work in. The questions asked for their own perspective on how shows the classification of answers to general questions on the use of standards. The answers are shown distributed between the three sets i, ii, and iii.

As can be seen in table 5.4, the answers of the majority of respondents to all of the questions fell in set ii, that is to say, the respondents knew that a standard existed, but as the standard was not understood, it was ignored.

Table 5.4 General questions regarding the organizational attitudes to standards, regulations and certifications which are in use in the organization.

Type of standards	Questions	Answers classified into sets i, ii and iii* Set ii is subdivided by organization type**. (Percent of answers in set ii)					
		i	ii				iii
		∑i	∑ii	∑ii A /nA	∑ii B/nB	∑ii C/nC	∑iii
Professional standards	1. Are these standards included in daily work procedural guidelines?	35	145 (74%)	1 /33 (3%)	4/6 (66%)	140/156 (90%)	15
	2. Are instructions including the standards given, along with explanations in training sessions in the organization?	28	135 (69%)	0/33 (0%)	3/6 (50%)	132/156 (85%)	32
	3. Is the implementation of these standards supervised by appropriately qualified personnel?	28	132 (68%)	0/33 (0%)	4/6 (66%)	128/156 (82%)	35
	4. Are corrective measures taken after failures are detected related to these standards?	35	125 (64%)	1/33 (3%)	3/6 (50%)	121/156 (77%)	40
Energy Efficiency and environmental protection standards	1. Are these standards included in daily work procedural guidelines?	35	145 (74%)	5/33 (15%)	5/6 (83%)	135/156 (86%)	15
	2. Are instructions including the standards given, along with explanations in training sessions in the organization?	28	135 (69%)	5/33 (15%)	4/6 (66%)	126/156 (81%)	32
	3. Is the implementation of these standards supervised by	28	132 (68%)	1/33 (3%)	6/6 (100%)	125/156 (80%)	35

	appropriately qualified personnel?						
	4. Are corrective measures taken after failures are detected related to these standards?	30	125 (64%)	2/33 (6%)	2/6 (33%)	121/156 (78%)	40
Risk Assessment Standards	1. Are these standards included in daily work procedural guidelines?	35	145 (74%)	0/33 (0%)	0/6 (0%)	145/156 (93%)	15
	2. Are instructions including the standards given, along with explanations in training sessions in the organization?	28	135 (69%)	0/33 (0%)	6/6 (100%)	129/156 (83%)	32
	3. Is the implementation of these standards supervised by appropriately qualified personnel?	28	132 (68%)	0/33 (0%)	5/6 (83%)	127/156 (81%)	35
	4. Are corrective measures taken after failures are detected related to these standards?	30	125 (64%)	0/33 (0%)	2/6 (33%)	123/156 (79%)	40

n: Total number of questionnaires completed. n = 195, nA=33, nB=6, nC=156

* i: the standards are not known, ii: standards not understood, iii: standards known, understood and used

** ∑ = sum total number of answers falling in set i from all three organizations; ∑ii = total sum of answers falling in set ii; ∑ ii A = total number of answers falling in set ii from health centres; ∑ii B = total number of answers falling in set ii from outsourcing organizations; ∑ ii C total number of answers falling in set ii from all other SMEs

As the study was particularly interested in situations where the standards were not applied because the personnel did not understand them, the questionnaires where the answers given could be classed in set ii were divided according to the type of organization the interviewee was working for. , 'A' signifies small /medium sized healthcare institutes (33 questionnaires in total), 'B' signifies organizations which offer external and outsourcing services (6 questionnaires in total) and 'C' signifies other types of organizations participating in the study (156 questionnaires in total).

Looking at table 5.5 it can be seen that the percentage of answers falling in set ii (Standards were known, but not understood,) were lower in healthcare workers than in other types of organizations. Indeed, most of the answers from maintenance workers at health care organizations could be categorized in the third set, meaning that the standards are known, included in work guidelines, implemented, taught in training sessions and checked by personnel qualified to do so.

This finding is important as these health care organizations are distinguished from the others by the training given to personnel. If extra training meant that standards were understood, and therefore implemented, it would seem possible that the reason for lack of implementation of standards which was leading to accidents may have been found. This gave the underlying rational for the action research looking at what kind of training could improve the situation, by ensuring standards were properly understood and followed. As will be discussed in chapter 6, this action research was informed by my reading of organizational learning and practice-based knowledge.

Table 5.6 shows that most answers indicating that regulations are known and followed were given for question 3 which asked whether only those regulations required by insurance requirements are followed. However, even in the case of requirements from insurance companies, most of the answers fitted the second category, that the regulations were not understood. The questions relating to regulations from within the organization, showed that these regulations were followed to a similar extent as those from insurance companies. The question relating to regulations in standards revealed that these regulations were most often ignored.

Table 5.6 also shows that highest percent of answers from healthcare centre workers falling in category ii were to the question ‘Personnel are used depending upon availability’. Five of the employees from health care institutes gave an answer agreeing in principle with the statement. In response to the statement ‘IEEE & IEC standards are in use together with local regulations’ only three of the employees from all types of organizations gave a response that could be coded ‘iii’ meaning that in only three cases were the employees convinced that the standards are in use. Between 3-9% of interviewees working in healthcare centres gave answers in category ii to all the other questions. By contrast, over 70% of answers to all the questions from respondents who were not working in healthcare centres, and were not employed by outsourcing bodies, fell in this category.

Table 5.5 Distribution of answers falling in category ii

Type of standards	Questions	Numbers of interviewees giving an answer in set ii over n.* according to organization type**			Total number of interviewees responding ii
		A (n=33)	B (n=6)	C (n=156)	
Professional standards	1. Are these standards included in daily work procedural guidelines?	1 / 33 3%	4/6 66%	140/156 90%	145
	2. Are instructions including the standards given, along with explanations, in training sessions in the organization?	0/33 0%	3/6 50%%	132/156 85%	135
	3. Is the implementation of these standards supervised by appropriately qualified personnel?	0/33 0%	4/6 66%	128/156 82%	132
	4. Are corrective measures taken after failures are detected related to these standards?	1/33 3%	3/6 50%	121/156 77%	125
Energy Efficiency and environmental protection standards	1. Are these standards included in daily work procedural guidelines?	5/33 15%	5/6 83%	135/156 86%	145
	2. Are instructions including the standards given, along with explanations in training sessions in the organization?	5/33 15%	4/6 66%	126/156 81%	135
	3. Is the implementation of these standards supervised by appropriately qualified personnel?	1/33 3%	6/6 100%	125/156 80%	132
	4. Are corrective measures taken after failures are detected related to these standards?	0/33 0%	0/6 0%	145/156 93%	125
Risk Assessment Standards	1. Are these standards included in daily work procedural guidelines?	0/33 0%	6/6 100%	129/156 83%	145
	2. Are instructions including the standards given, along with explanations in training sessions in the organization?	0/33 0%	5/6 83%	127/156 81%	135
	3. Is the implementation of these standards supervised by appropriately qualified personnel?	0/33 0%	2/6 33%	123/156 79%	125
	4. Are corrective measures taken after failures are detected related to these standards?	0/33 0%	0/6 0%	145/156 93%	145

*Set ii indicates the interviewee knows a standard exists, but it is not followed. from each organization type, n= total number of filled questionnaires for this organization type.

**A=Health centres, B= Outsourcing, C= Other organizations

After the general questionnaire was answered, more detailed questions were asked as to the interviewees' perceptions as to which types of standards and regulations are in use in the

organization they work with. The questions also explored whether employees are selected in line with regulations. The questions were formulated together with the body accompanying the research (MATI) following the study of the accident reports. The findings are shown in table 5.6. The total number of questionnaires, n = 195

Table 5.6 Imposition of standards and selection of personnel

Q.	Topics relating to regulations in use in the organization, from the perspective of personnel	Answers classified into sets i, ii and iii* Set ii is subdivided by organization type**. (Percent of answers in set ii)					
		i	ii				iii
		∑i	∑ii	∑iiA/nA	∑iiB/nB	∑iiC/nC	∑iii
1	IEEE & IEC standards are in use, together with local regulations.	27	155 (79%)	0/33 (0%)	3/6 (50%)	152/156 (97%)	3
2	Only imposed and verified regulations are used.	15	145 (74%)	3/33 (9%)	6/6 (100%)	136/156 (87%)	35
3	Only insurance requirements are imposed.	5	128 (66%)	1/33 (3%)	6/6 (100%)	121/156 (76%)	62
4	Organizational procedures are used.	3	135 (69%)	1/33 (3%)	5/6 (83%)	129/156 (83%)	57
5	Prerequisite certifications and accreditations are verified.	3	135 (69%)	0/33 (0%)	0/6 (0%)	135/156 (86%)	57
6	Known and recommended workers are selected.	5	132 (67%)	2/33 (6%)	2/6 (33%)	128/156 (82%)	58
7	Occasional personnel are used.	45	135 (69%)	2/33 (6%)	2/6 (33%)	131/156 (84%)	15
8	Personnel are used depending upon availability.	25	155 (79%)	5/33 (15%)	2/6 (33%)	148/156 (95%)	15
9	Management supplied personnel are used.	21	158 (81%)	2/33 (6%)	0/6 (0%)	156/156 (100%)	14
10	No departmental personnel descriptions are imposed.	23	160 (82%)	2/33 (6%)	6/6 (100%)	152/156 (97%)	12

n: Total number of questionnaires completed. n = 195, nA=33, nB=6, nC=156

* i: the standards are not known, ii: standards not understood, iii: standards known, understood and used

** ∑ = sum total number of answers falling in set i from all three organizations; ∑ii = total sum of answers falling in set ii; ∑ ii A = total number of answers falling in set ii from health centres; ∑ii B = total number of answers falling in set ii from outsourcing organizations; ∑ ii C total number of answers falling in set ii from all other SMEs

5.3.2 Questions about the composition of maintenance departments

Personnel were asked about the composition of the maintenance departments. The goal of this question was to compare the personnel's description of the organization of the maintenance department with the description given by the organization's management. The first division was whether the maintenance department is 'in house' or 'outsourced'. As discussed in section 2.5, this had been the focus of initial studies into why accidents were occurring in association with maintenance work. Furthermore, as discussed in section 2.5 outsourcing had been initially viewed as solution to all organizational problems regarding maintenance work, but was shown to create communication problems, and complex management chains. When asked an open-ended question about the organization of the maintenance department numerous variations were given on the 'in-house' versus 'outsourced' theme. These included: "In-house"; "In-house, locally managed", "In-house, externally managed", "In-house, with split management", "partially-in house", "partially in-house, locally managed", "partially in-house, externally managed", "partially in-house with split management", "outsourced", "outsourced locally managed" and "outsourced externally managed". The management of maintenance departments which are In-house, and managed locally by people on the site, or a department with an outsourced maintenance department, managed externally, would seem to be clearly defined. However, interim cases with split management, and teams that are partially in-house and partially outsourced, it seemed that there was a great deal of uncertainty about the nature of the management.

When asked whether the organization of the maintenance department was governed by standards or regulations, there was an even distribution of answers from not knowing about the existence of regulations, thinking that there were regulations, but they were too complicated to understand and knowing what the regulations were, and claiming that these were followed. There was also no correlation between the type of organization and the organization of the maintenance department. Furthermore, unlike in the case of the more general questions, the maintenance workers in healthcare organizations did not seem to know more about standards governing the composition of their department than workers in the other types of organizations. It is possible that this was considered a management issue not relevant to the maintenance workers and therefore not included in their training.

5.3.3 Interviews asking about certification, supervision and guidance

The interviews were aimed at establishing how the department personnel function in reality in comparison to regulations and standards describing management in organizational work procedures or charters. Before the interviews were carried out, I had to ascertain the level of personnel certification and licensing for each type of maintenance worker in all of the different environments. These then had to be compared with the answers and descriptions given in the interviews. The findings presented in Table 5.7 summarise the interviewees' views and understanding. This comparison demonstrates the gap between the declared organizational behaviour towards standards and regulations versus reality from the perspective of the personnel. Once more the heaviest weighted answers in all categories were those indicated by the answers categorized as belonging to set ii. This indicated that interviewees were aware of standards existing for certification, licensing, quality evaluations and discussions of work problems, but the standards are not understood and are ignored.

Standards and regulations include demands that all work is properly supervised and evaluated. They also include detailed descriptions of the licences, training and certification required for different types of personnel working in different organizations. Furthermore, there are precise descriptions of work methodologies. The standards also demand corrective measures and dialog on any problems occurring during the maintenance work. The large numbers of answers matching the definitions of column i (standards are not known) point to problems on the ground in these areas. The table shows that important issues are not dealt with in ways matching standard requirements. The interview answers falling in set ii are shown according to the type of organization. Few interviewees from health care centres gave answers that indicated they did not understand the standards.

Table 5.7 also shows the percentage of interviewees from each type of organization whose answers indicated that the standards were not understood. Very few of the answers from interviewees working in maintenance of healthcare centres, could be classified as belonging to set ii. In almost all cases less than 10 % of the maintenance workers indicated that the standards were not understood, with between 10 and 20% of interviewees indicating they did not understand the standards asked about in two questions (no. 8 and no. 9). As question 8 related to instructions for the use of machines, it would appear that even workers in health care centres may need some extra training to ensure they understand important standards.

Table 5.7 Certification, supervision and guidance of maintenance workers. N=195

Q.	**Licensed and / or certified**	Answers classified into sets i, ii and iii* Set ii is subdivided by organization type**. (Percent of answers in set ii)					
		i	ii				iii
		∑i	∑ii/n	∑iiA/nA	∑iiB/nB	∑iiC/nC	∑iii
1	Are there licenses or certification relevant to your work in the maintenance department?	35	85/195 44%	1/33 (3%)	6/6 (100%)	78/156 (50%)	75
2	Do you work on maintenance tasks requiring license or certification?	33	88/195 45%	1/33 (3%)	6/6 (100%)	81/156 (52%)	74
3	Do you hold personal licenses or certification?	40	88/195 45%	2/33 (6%)	6/6 (100%)	80/156 (51%)	67
4	Does the Organization hold licenses or certification for the maintenance work carried out?	65	88/195 45%	2/33 (6%)	3/6 (50%)	85/156 (54%)	42
5	Are these licenses or certifications given by external bodies?	44	104/195 53%	0/33 (0%)	4/6 (67%)	100/156 (64%)	47
6	Does your department have licensing or certifications for working with Outsourced labour?	48	107/195 55%	0/33 (0%)	4/6 (67%)	103/156 (66%)	40
7	Are there job descriptions for each task with guidance?	48	107/195 55%	1/33 (3%)	3/6 (50%)	103/156 (66%)	40
8	Are the job descriptions, instructions for the use of machines and any other guidance given clear to you?	40	107/195 55%	6/33 (18%)	3/6 (50%)	98/156 (63%)	48
9	Is there a clear methodology for each job, and is this in accordance with regulations?	35	112/195 57%	5/33 15%	3/6 (50%)	104/156 (67%)	48
10	Is the quality of the work done evaluated, in comparison to standards?	33	122/195 63%	2/33 (6%)	3/6 (50%)	117/156 (75%)	40
11	Are problems discussed in relation to standards?	22	140/195 72%	2/33 (6%)	2/6 (33%)	136/156 (87%)	33
12	Are problems occurring during maintenance work corrected, and brought into line with standards?	32	130/195 67%	1/33 (3%)	2/6 (33%)	127/156 81%	33

n: Total number of questionnaires completed. n = 195, nA=33, nB=6, nC=156

* i: the standards are not known, ii: standards not understood, iii: standards known, understood and used

** ∑ = sum total number of answers falling in set i from all three organizations; ∑ii = total sum of answers falling in set ii; ∑ ii A = total number of answers falling in set ii from health centres; ∑ii B = total number of answers falling in set ii from outsourcing organizations; ∑ ii C total number of answers falling in set ii from all other SMEs

By contrast, all of the interviewees employed by outsourcing organizations gave answers indicating they did not understand the standards asked about in the first three questions. As these questions ask about personal licensing, and licensing needed in order to undertake

specific jobs, it would seem that there is an urgent need for change in these organizations. Furthermore, half of these workers indicated that they do not understand instructions for the use of machines. This indicates an urgent need for more training related to these standards.

Another trend shown in table 5.7 is that over 40 interviewees (20% of all respondents) claimed that standards were not know to them in answer to questions 3,4,5,6,7 and 8. These questions referred to licensing and certifications as well as to job descriptions. This finding was particularly worrying, and supported the importance of coaching sessions explaining standards.

Over half of the interviewees working in organizations apart from healthcare centres and outsourcing bodies, responded that they did not understand the standards in answer to all of these questions asked. This again emphasizes the urgent need for change. The answers reinforced my conviction that coaching sessions explaining relevant standards could be the way to initiate that change.

5.3.4 Interviews asking about safety standards, environmental protection and energy efficiency standards and risk assessment standards.

The next set of interview questions asked about the interviewees' understanding of regulations relating to safety; energy efficiency and environmental protection; and risk assessments. The questions also asked about more specific regulations, including local, national and international standards; demands from insurance companies; and more detailed questions about instructions and regulations for working with specific types of machines and regulations related to specific professions. Table 5.8 presents the distribution of the answers in sets i, ii and iii and the distribution of the answers that fell in set ii according to the types of organization where the interviewees work.

Table 5.8 Understanding of safety standards, environmental protection and energy efficiency standards and risk assessment standards

Q.	**Manpower / staff knowledge of standards and regulations**	Answers classified into sets i, ii and iii* Set ii is subdivided by organization type**. (Percent of answers in set ii)					
		i	ii				iii
		∑i	∑ii	∑iiA/nA	∑iiB/nB	∑iiC/nC	∑iii
1	Safety standards.	45	105/195 54%	2/33 6%	3/6 50%	100/156 64%	45
2	Energy efficiency and environmental standards.	55	115/195 59%	5/33 15%	1/6 17%	109/156 70%	25
3	Risk assessment standards.	65	95/195 49%	2/33 6%	0/6 0%	93/156 60%	35
4	Local and national regulations.	75	85/195 44%	2/33 6%	2/6 33%	81/156 52%	35
5	Insurance specific definitions.	65	105/195 54%	2/33 6%	2/6 33%	101/156 65%	25
6	Organizational working procedures.	80	105/195 54%	0/33 0%	1/6 17%	104/156 67%	10
7	International standards.	83	103/195 53%	0/33 0%	1/6 17%	102/156 65%	9
8	Local standards.	80	98/195 50%	0/33 0%	4/6 67%	94/156 60%	17
9	Regulations and limitations.	88	97/195 50%	0/33 0%	4/6 67%	93/156 60%	10
10	Specific machine related instructions.	58	117/195 60%	0/33 0%	5/6 83%	112/156 72%	20
11	Specific regulations for manpower.	38	132/195 68%	6/33 18%	6/6 100%	120/156 79%	25
12	Hierarchical professional regulations.	8	142/195 72%	4/33 12%	6/6 100%	132/156 85%	45

n: Total number of questionnaires completed. n = 195, nA=33, nB=6, nC=156

* i: the standards are not known, ii: standards not understood, iii: standards known, understood and used

** ∑ = sum total number of answers falling in set i from all three organizations; ∑ii = total sum of answers falling in set ii; ∑ ii A = total number of answers falling in set ii from health centres; ∑ii B = total number of answers falling in set ii from outsourcing organizations; ∑ ii C total number of answers falling in set ii from all other SMEs

It can be seen from table 5.8 that over 40% of all answers to all questions were categorized in set ii meaning that standards were not understood, and therefore were not implemented. In the case of safety standards, 45 interviewees (23%) stated that they were unaware of the standards and another 45 interviewees stated that they were familiar with the standards and implemented them in their work. Over 50% of interviewees replied that they knew that

relevant standards existed, but did not implement them, because they could not understand them. This finding emphasized once again the urgent need for coaching sessions that could explain the standards in simple language, to be introduced into work routines. Safety regulations are written to protect the workers and the general public. They were often introduced in response to accidents. If they are ignored, it is reasonable to predict that these accidents will reoccur.

A similar situation was seen for energy efficiency and environmental protection standards. In this case, less interviewees responded that they knew and understood the standards and followed them in their work. It is possible that the technical terms in these standards are particularly complex. Over 60% of interviewees responded that they did not understand the standards relating to two questions asking about specific regulations for use of machinery and working instructions for manpower.

When looking at the distribution of those interviewees who gave answers that were categorized as fitting set ii, it is again seen that few interviewees from healthcare institutes gave answers that fell in set ii. A high proportion of maintenance workers from outsourcing companies admitted that they did not understand specific regulations related to the use of machinery (83%) and regulations related to manpower (100%). Over 60% of interviewees from the other organization types included in the study responded to all of the questions that they did not understand the standards and regulations related to safety, risk assessment, environmental protection and energy efficiency. Once again, this grave situation revealed by the study needs urgent attention.

5.3.5 Record Keeping

One important aspect of workplace protocols relates to record keeping in relation to faults, repairs and deficiencies in equipment and tools accessible or held by the department. During the interviews, personnel were asked detailed questions about how records of faults, equipment failures and inadequacies are kept. Table 5.9 summarises the organization's attitudes towards equipment records in reality, which often contrast strongly with declared attitudes. During the interviews it was obvious that there was a high level of confusion. The maintenance personnel lacked clarity about what they were expected to accomplish. This table describes the requirements formulated by different organizational stakeholders, internal and external, relying on the known and published documents. This table explicitly shows that not only the issue of

record keeping is generally mistreated but also that some specific issues are nearly completely ignored.

Table 5.9 Records of equipment deficiencies, failures and repairs

Q.	**Deficiencies, equipment faults and other unpredicted occurrences records keeping**	Answers classified into sets i, ii and iii* Set ii is subdivided by organization type**. (Percent of answers in set ii)					
		i	ii				iii
		∑i	∑ii	∑iiA/nA	∑iiB/nB	∑iiC/nC	∑iii
1	Records related to professional standards.	42	133/195 (68%)	2/33 (6%)	1/6 (17%)	130/156 (66%)	20
2	Records related to energy efficiency and environmental standards.	44	123/195 (63%)	2/33 (6%)	1/6 (17%)	120/156 (77%)	28
3	Records related to risk assessments.	34	143/195 (73%)	0/33 (0%)	2/6 (33%)	141/156 (90%)	18
4	Organizational formulated forms.	24	145/195 (74%)	3/33 (9%)	2/6 33%	140/156 (90%0	26
5	Periodical recorded checks of machinery	38	155/195 (79%)	0/33 (0%)	2/6 (33%)	153/156 (98%)	4
6	Records aimed at specific machinery defect/repair cost.	55	105/195 (54%)	0/33 (0%)	1/6 (17%)	104/156 (67%)	35
7	Weather and climate related recorded operations forms.	54	115/195 (59%)	9/33 (18%)	0/6 (0%)	106/156 (68%)	26
8	Obligatory insurance requirements for coverage.	34	125/195 (64%)	2/33 (6%)	6/6 (100%)	117/156 (75%)	36
9	Forms for actions required by regulations.	23	145/195 (74%)	3/33 (9%)	2/6 (33%)	140/156 (90%)	27
10	Recording of regulated sequenced time actions.	75	45/195 (23%)	3/33 (9%)	6/6 (100%)	36/156 (23%)	75
11	Recording of regulated equipment related actions.	78	45/195 (23%)	3/33 (9%)	6/6 (100%)	36/156 (23%)	72
12	Actions described, predicted and forecasted in Standards.	65	98/195 (50%)	2/33 (6%)	4/6 (67%)	92/156 (59%)	32

Glancing at table 5.9 shows that the consistent pattern of the distribution of answers categorized as fitting set ii has continued. This was a feature of the entire study. Standards were fairly well known and understood by maintenance manpower working in healthcare centres. However, a large proportion of people doing similar jobs in other organization types gave interviews indicating that although they knew standards existed in the topics asked about, they did not understand the complex language and therefore ignored the regulations. If proper records are not kept for safety evaluations it is hard to carry out proper accident investigations. These investigations are a crucial tool in improving workplace safety. If proper records are not kept for risk assessments, this hinders the improvement of risk management in the future.

Tables 5.10 and 5.11 continue with a verification of the personnel deficiencies in record keeping.

Table 5.10 Record Keeping

Q.	**Record keeping**	Classification of answers into sets * n**=195		
		i	ii	iii
1	Records elaborated and specified by department.	42	133	20
2	Records used for work price evaluation.	44	123	28
3	Records elaborated and specified by machine manufacturer.	34	143	18
4	Records elaborated and specified by insurance bodies.	24	145	26
5	Specific formulation according to insurance reports.	36	155	4
6	Records specified by standards.	55	105	35
7	Records specified by regulations.	54	115	26
8	Records studied and discussed by department personnel.	34	125	36
9	Records formulated for periodical internal / external report.	23	145	27
10	Records formulated for safety evaluation.	45	105	45
11	Records formulated for efficiency evaluation and environmental verifications.	48	105	42
12	Records formulated for risk assessments.	55	108	32

* i: the standards are not known, ii: standards not understood, iii: standards known, understood and used

**n: total no. of questionnaires completed,

Table 5.11 presents the distribution of answers that fit in the set which indicates that standards were not understood according to the type of organization the interviewee worked for.

Table 5.11 Distribution of answers from set ii in table 5.10 -record keeping

Q.	**Record keeping**	Numbers of interviewees giving an answer in set ii* according to organization type**		
		A (n=33)	B (n-6)	C (n=156)
1	Records elaborated and specified by department.	0	0	133
2	Records used for work price evaluation.	0	0	123
3	Records elaborated and specified by machine manufacturer.	3	6	134
4	Records elaborated and specified by insurance bodies.	3	6	136
5	Specific formulation according to insurance reports.	3	6	148
6	Records specified by standards.	2	2	101
7	Records specified by regulations.	3	6	106
8	Records studied and discussed by department personnel.	2	0	123
9	Records formulated for periodical internal / external report.	2	0	143
10	Records formulated for safety evaluation.	0	2	62
11	Records formulated for efficiency evaluation and environmental verifications.	2	0	103
12	Records formulated for risk assessments.	5	2	101

*Set ii indicates the interviewee knows a standard exists, but it is not followed. n= total number of filled questionnaires for this organization type.

**A=Health centres, B= Outsourcing, C= Other organizations

5.3.6 Unconventional and unexpected work

The final stage of the interviews further explored employees' declared knowledge of standards and regulations regarding unconventional and unexpected tasks. It is very important to emphasize the standards for use in these types of jobs as they are marked as "must know" and "must comply with" in regulatory and standards documents. Surprisingly, despite the acknowledgement within the organizations of the character of these documents and their agreement that it is obligatory to comply with them, in the research a very similar pattern was obtained to that shown in the previous tables. This further demonstrates the need to initiate corrective action in these organizations. Despite the fact that this table is presented last, the findings presented in it represents the core reason for this research.

Over the last two decades there has been a multiplication of unconventional and unpredicted maintenance tasks related to risk assessments, environmental protection and energy effectiveness. The expectation is that these will be covered by maintenance personnel, who may be in-house employees or outsourced personnel brought in for the tasks. Many different standards and regulations demand that these tasks are completed at certain times, although these may be related to particular circumstances rather than being scheduled at particular time intervals.

The interviews also revealed that only organizations which are frequently confronted with these issues are aware of the existence of standards. Open ended questions were given answers that indicated that almost all of the organizations still prefer to ignore these standards, essentially due to their complexity. The questions asked about jobs completed on a daily /weekly /yearly basis as well as jobs done when the situation demanded special attention. Employees were also asked whether their team covers all types of work or whether they bring in external help for irregular unconventional events and work hours.

Table 5.12 presents how the answers to questions about knowledge and implementation of standards and regulations regarding irregular unconventional working times / exceptional events and failures were distributed. The questions explored whether the interviewees perceived standards to be supervised by the organization's management or by other personnel. This attempted to look at the management hierarchy with regard to standards. When there is a lack of certainty as to where responsibility lies for supervision of irregular tasks, happening at unconventional times, it is conceivable that supervision slips between the cracks, and may not take place.

Table 5.12 Unconventional and Unexpected work

Q.		Classification of answers into sets * n**=195			Numbers of interviewees giving an answer in set ii* according to organization type***		
	Professional Standards	i	ii	iii	A	B	C
1	Covered internally by organizational personnel	23	145	27	1	6	138
2	Covered by outsourced personnel	45	105	45	0	0	105
3	Covered by internal and outsourced personnel	55	108	32	0	4	104
4	Covered by equipment supplier personnel	48	105	42	1	0	104
	Energy efficiency and environmental protection standards						
5	Covered internally by organizational personnel	42	133	20	1	0	132
6	Covered by outsourced personnel	44	123	28	2	0	121
7	Covered in common by internal and outsourced personnel	24	145	26	0	0	145
8	Covered by equipment supplier personnel	34	143	18	1	0	142
	Risk assessment overall standards						
9	Covered internally by organizational personnel	36	155	4	2	6	147
10	Covered by outsourced personnel	55	105	35	1	0	104
11	Covered by internal and outsourced personnel	34	125	36	1	0	124
12	Covered by equipment supplier personnel	48	105	42	1	0	104

* i: the standards are not known, ii: standards not understood, iii: standards known, understood and used

**n: total no. of questionnaires completed,

*** A=Health centres, B= Outsourcing, C= Other organizations

If we look back at the answers given to the first set of interviews, it can be seen that there is a similar distribution throughout all tables, with the highest number of answers to all questions categorized in set ii. The interviewees knew these standards existed, but did not understand them. These standards and regulations impose corrective actions, behaviour, knowledge and reporting of these failures on organizations. The findings presented in Table 5.12 shown in column A indicate that few interviewees working at Small /medium sized Healthcare Institutes gave answers that fall in set ii. From my personal experience of working with these types of organizations, he is aware that these organizations give more intensive training and are that all workers are continuously supervised. Open ended questions at the start of the interview process also confirmed this.

5.4 Themes emerging in the answers to the interviews.

5.4.1 Work procedural guidelines do not match directives in Standards

In preparation for a discussion about the results and conclusions, I divided the findings into sections. In all the cases where I found that work guidelines do not match standard directives, I selected the findings which could be worked on and resolved in order to lead to practical changes which may be implemented.

For example, in large air conditioning systems where maintenance work is performed on the roofs of the buildings there are requirements as to the composition of the staff, defined as follows: a qualified air conditioning technician together with an authorized electrician and another general worker. In all the maintenance departments where the interviews were carried out for the research, there was not even one single case where an air conditioning technician worked alongside an authorized electrician in the teams handling the air conditioning systems. Some of the sites included in the study had air conditioning technicians and others had electricians who knew how to handle air conditioning systems and, in this manner, when the work requires it, the leading professional gets the help of any employee according to the temporary need that defines the operation being carried out.

The following should be noted here as a clarifying example: The standard that discusses the maintenance of large air conditioning systems has no definition of the term "large" and therefore when the site has an air conditioning system on the roof it automatically enters the standard definition of "big" even if in fact it is not a large system, and its maintenance does not require the manpower specified in the standard. As a result of the lack of compatibility between the definitions of existing systems and those listed in the standards, I sought a way to work around the differences. A suitable definition was needed that would enable the organization to maintain the systems and meet the standards requirements. This case includes three sets of standards: Safety, efficiency and environmental protection, and risk analysis.

The questions that arose here were also derived from not having any defined answer as to who should decide which standards to use. Sometimes there are actually other standards that include the answer, but no one is aware of them. In the case of the rooftop air-conditioning units, I found that there are standards that deal with the maintenance of electromechanical systems on the roof of a structure. These standards meet all the requirements and are detailed

in the three sets of standards that define the maintenance work in the different organization types. When using these standards, the issue of the size of the system is no longer a problem. After considering the specific case discussed in this example, the maintenance teams could easily understand the main standard governing the maintenance of large air conditioning systems. It was possible then to conclude that a standard for large organizations may be incompatible with these SMEs. This did not mean that all standards in this field should be ignored, but rather that there are other standards that cover the same actions performed that are compatible with SMEs. These standards can be introduced into the guidelines for work procedures. The inclusion of a coaching element can also ensure implementation of the standard.

5.4.2 Difficulties in understanding and implementing standards

During many my years of experience studying the regulations included in standards relevant to maintenance work and teaching these regulations to others, I had accumulated a growing appreciation of the problematic nature of the formulation of these regulations. Standards organizations conduct regular reviews of written standards; however, they aim their texts at highly trained professionals. The emphasis is on including all of the necessary information in the regulations, to exonerate those writing the standards from responsibility, if disastrous events occur. However, there is no emphasis on making the information clear and understandable. The review boards include representatives of the leading firms involved in writing standards. They do not include people working as technicians in the field of maintenance, who may inform the board on whether the regulations are easily understood.

The composition of standards' committees is itself dictated by international regulations. However, the standards still include formulations adapted to specific professional bodies, elaborated in a way that is unclear, or practically incomprehensible to the general professional population. This is not to imply that these methodologies are purposely formulated in a way stopping them from being understood by the general professional public. However, these standards are formulated by professionals in the best way they can. They aim for them to be as short as possible in highly technical language covering all aspects of the subject specified in the standard. The issue resides in the complicated language which is difficult or impossible to understand by maintenance personnel leading to the sad state of

affairs which is gaining increasing press coverage as time goes by and to the results as presented in this work. The analysis of the questionnaires led to several insights into the difficulties faced by professionals working in organizational maintenance departments when trying to comprehend, internalize, adopt and incorporate the standards into organizational work procedures.

5.4.3 Apprehension and fear.

Looking at tables 5.4 to 5.12 constructed from initial analysis of the interviews immediately reveals that a large majority of answers indicate a lack of understanding of the standards. During the interviews I held with the personnel I became aware that this lack of understanding promulgated a sense of fear or apprehension about addressing the whole issues of standards.

Many of the answers included phrases found below (translated from the Hebrew):

“Most of our co-workers (including us) do not understand standards.”

“No one tries to explain standards to us. We just use work methods we have always used.”

“If someone does try to explain standards, it makes us nervous. We are not sure whether we should ask questions when we don’t understand something. The atmosphere can become very tense.”

“When we are given explanations that we don’t understand, we usually just ignore them and use the methods we had been using before.”

“If someone talks about standards and uses language that I don’t understand it makes me feel uncomfortable. I don’t want to appear unable to do my job”

The interviewees revealed a reluctance to even attempt to learn to use standards and to assimilate them into the organizational work procedures. Within the group of professionals who answered the interview questions, I found that those who worked in organizations with more apparent regulation (small or medium medical institutions and outsourcing organizations) were extremely reluctant to learn more standards. They were also reluctant to attend coaching sessions which may lead to more difficulties in implementing yet more regulations.

Answers given by workers included phrases such as those below (translated from Hebrew).

“We are given briefings with specific requirements and told to be careful. We are already aware of risks from our previous experience”

“If standards are added to the explanations and we don’t understand them, then we carry out the work the way we think best”

“Sometimes another professional is asked to supervise our tasks, but this is rare. It is not something we ask for”

In general, the attitude to learning more about standards was negative before experiencing coaching sessions.

5.4.4 The age and experience of the interviewees

In analysing the responses given by healthcare institutions, I found that the younger workers (with limited professional experience in the specific place of work) had lower levels of knowledge. This group was found to be more apprehensive of standards than workers with more experience. This result was found also in other types of organizations but was less eminent.

5.4.5 The importance of training and supervision

The training and supervision in medical workplaces does reinforce knowledge and implementation of standards. This occurs to a greater degree in healthcare institutes than in other types of organizations. However, in all types of organizations these training sessions only go as far as the point where the basic standards are understood. Those parts of the standards that the personnel involved in training have difficulty in understanding are ignored. Therefore, training is stopped and, in some cases, critical standards are not implemented in the organizations’ work procedures.

5.4.6 The importance of clear language that is easily understood.

During the interviews, the three selected areas of standards covered in the research were presented to the interviewees. This allowed me to ascertain which parts of the standards were understood – and which were incomprehensible, and required clarification and explanation. This process clearly demonstrated the degree to which the interviewees had difficulty in understanding the regulations, due to the way they were phrased. Whenever the regulations

were explained in simplified, less technical language, they were understood. By undertaking these procedures, the fear and apprehension of dealing with standards could gradually be removed. When the important information from the standards was rephrased into simpler language, the standards can be incorporated into the work procedures of the organization. Thus, organizations will have updated procedural guidelines that fulfil the authorities' and insurance companies' requirements according to the definitions specified in all relevant standards.

5.4.7 Summary of key findings from the interviews

While the examples of answers to interview questions presented in section 5.1.2 offer a rich picture of what takes place in maintenance departments (see sections 3.4.3; 4.1.3 and 4.2.3) that clearly demonstrates that standards are not complied with in many maintenance tasks, the findings from the interviews presented in tables 5.2 to 5.12 all demonstrate that the lack of understanding of the standards was the main for the lack of compliance with them. The findings also inform the reader how the organizations are dealing or failing to deal with conflicts between standards and procedural guidelines. The key message from the interviews was that there is a gap between the actions which should be taken to resolve the issue of accidents relating to maintenance work and how the organizations are approaching these issues de-facto. Instead of undergoing a learning experience from their experiences, the departments continue to work in the same way, without fully engaging with the problem that crucial safety standards are not implemented.

This endorses the choice of theoretical framework for the study as laid out in sections 2.5.1; 2.5.2; 2.5.3; 2.5.4 which deal with organizational learning and knowledge management. From the earliest stages of the study the reverse engineering approach (sections 2.5.1 and 4.2.4) revealed that currently in maintenance departments safety standards are not implemented and that this leads to accidents. Following Argyris' theory of double loop learning, (as discussed in sections 2.5.1 and 4.2.4) the question that needed to be answered was not simply **what** was happening in the maintenance departments, i.e. understanding the extent to which safety standards were not being implemented, but **why** this was happening. The open-ended questions of the interviews, revealed rich pictures (see sections 3.4.3; 4.1.3; 4.2.3) of what was actually taking place on the ground, revealing that Standards are not implemented because they are not understood. This indicates that an active process of learning was necessary throughout the organizations involved in the study. As will be discussed in the next section, the next stage of the MGAR was interaction coaching sessions.

Having personnel on-board for learning processes is essential to organizational learning as discussed in the various subsections of section 2.5 which explore theories of knowledge management and organizational learning important for a research practitioner.

5.5 Using the tabulated interview results to prepare for the Action Research based on interactive coaching sessions

The first goal of the research had been to understand why accidents related to maintenance work were occurring so frequently. It had become obvious to me from the review of accident investigations that many crucially important standards had not been implemented at sites where accidents took place. The division of answers given by maintenance personnel in the semi-structured interviews clearly showed that most personnel reported that they are aware of the existence of most kinds of standards, but do not implement them as they do not understand the complex language used in the standards. I saw that across the different types of standards, different professions amongst maintenance workers carrying out different types of jobs that most answers were categorized as fitting set ii, representing the answer: “I knew that there is a standard or guideline but because it is incomprehensible to me or not detailed in the organizational work procedure which I am familiar with, I ignored that standard / guideline”. Furthermore, maintenance departments in Small /Medium Sized Healthcare Institutes show proportionally the highest number of results belonging to the third set meaning: “the standards are well known and included and used in the organization's work procedures”. I was aware from his involvement in these institutes, and with the other organizations, that healthcare institutes have more rigorous supervision. The work done is also inspected more often. This could be expected considering the risks associated with the activities undertaken in these institutes. It is noted that the sample size was relatively small for these organizations.

I also explored whether the composition of the maintenance department and the level of education of the professionals operating and executing the work undertaken in each department influences the interviewees reports on their comprehension of standards. The initial questions asked yielded a big surprise: there was almost no difference at all in the comprehension of standards between the maintenance personnel with different levels of education. In some cases, technicians started explaining the meanings of standard formulations and the work requirements resulting from these directives, to fully qualified engineers. However, in most cases, there was a general lack of understanding at all levels.

This problem is even found in Small /Medium Sized Healthcare Institutes, where an adherence to standards and regulations is expected, imposed and verified. The only cases where there was a higher proportion of answers fitting set iii, were found in institutions in which continuous instructional training sessions were conducted. I ascertained this during the interviews and noted it on the forms during and after each interview. Following the completion of the interviews, it was decided that the only ethical approach seemed to be in following action research directed towards introducing change as quickly as possible. The University supported the action research approach for the study, including the concept of coaching to inculcate implementation of standards as rapidly as possible. The literature reviewed in throughout section 2.5 formed the theoretical basis for conducting the interactive coaching sessions, with more details given in the next section. As discussed in section 2.5.2 currently theories of organizational learning relate to an epistemology of action, with the company's knowledge being related through the pragmatist paradigm whereby knowing as an action rather than previously held views focussing on knowledge as a possession. The objective of the interactive coaching sessions is for knowing and learning to transform into practice, in line with pragmatist ontology and epistemology as discussed in section 3.2.1. In line with Bandura's behavioural theory of social learning (section 2.5.4) it was decided that role play would form an important part of the coaching sessions, allowing people to learn from imitation.

5.6 The Interactive Coaching Sessions

Following on from the results of the interviews as presented in section 5.4, I defined several aims of the interactive coaching sessions. In general, I intended the coaching sessions to enhance the understanding of the critical importance of engaging with safety standards and including them in work guidelines. In order for personnel to engage with the standards they had to not only realize their significance but also to fully understand them. As discussed in section 2.5.3 it is not an easy task to convince people to change the way people work, unless management demands this. Furthermore, as cogently described by Mingers, (2006) and discussed in section 2.5.3 many unpredictable and irrational factors may impede organizational learning and the dissemination of knowledge, including personal grudges, inflated egos or social conflicts. As a research practitioner, I do not represent management, however I did need endorsement from management to gain the support of the organizations. Management did not always understand my role in helping promote organizational learning. However, when I used terms like total quality management, and total performance management which were familiar to them, they became more supportive of the action

research phase of the study. Action research involves working together with the participants to initiate change. As stressed by Argyris' learning theories (1976s: see section 2.5.1) it is crucial to involve personnel and to create an atmosphere of cooperation to avoid conflicts and enable social learning. The importance of social and human aspects of working with people are stressed in many methodologies incorporating SSM in models of KM (Checkland, 1983, 1990; Mingers, 2006, 2014; Wilson, 2001). One of the keys to making a difference in thinking about incorporating new elements of theories and regulations in activities that have been approached in a certain way for decades is by making provocative use of theory (Ramsey, 2011). Taking the standards out of the dry setting of guidebooks and explaining them through examples that have occurred in maintenance work in their own departments or other departments carrying out similar tasks was pivotal to changing the attitudes of both management and employees.

5.6.1 General Themes found during coaching sessions.

The first reoccurring theme in coaching sessions, was the same as that found in the interviews: the lack of comprehension of complicated terminology used in standards. The second reoccurring theme related to the length of standards, which made it hard to find the correct details needed for a particular job. The third theme was that professionals were unaware of recently updated standards made for the new technology they were using. The fourth theme reoccurring from many of the interviews was that even when personnel knew of the existence of standards, they were not certain about which standards applied in which settings. A good example of these problems is found in the standards which exist for the installation of electrical panels. These panels are used in all maintenance departments. During preliminary discussions, maintenance professionals gave different "explanations" about how standards for electrical panels should be implemented. However, none of these explanations complied with the actual standards. The professionals dealing with electrical panels in different organizations all said that they were aware that there is a standard for electrical panels. However, the six parts of the IEC 60439 European and international standard is composed of 732 pages, with many of these pages describing, in very complicated terminology, specific parts and components of the panel. At the interview stage of the research, none of the interviewees were able to present a coherent knowledge of the standard to the interviewer. Some professionals were capable of describing information from presentations from sales staff of the commercial companies which supplied the organization with the electric panels. However, presentations given by sales staff were limited to specific

points which these suppliers were interested in presenting, as these were the suppliers' strong points. Furthermore, many of the points which, according to standards, must be verified by the purchasers were not included in these presentations. The presentations also did not include information on checking the panel delivery or the adequacy of the panel installation. With these details left unclear, maintenance personnel remained unaware of, and unfamiliar with, the Standards' demands. This resulted in a lack of compliance with the standards' demands for the electrical panel. The information in the IEC 60439 standard and the standard following it, IEC 61439, is critically important for safety at sites where maintenance work is being conducted. Yet during coaching sessions I found that these were the most misunderstood standards of all. Complicating this lack of comprehension, insurance companies also impose demands on most organizations. These add the regulations in American standards to the regulations in European ones, as insurance documentation refers to American Standards. This specific case of electrical panels standards demonstrates how a lack of clarity develops. The situation characterized by a lack of familiarity with standards, leads to dangerous situations. It is obvious that incorrect installation of electrical panels which do not conform to the Standards endangers everyone on a site. The inappropriate use of electrical panels by organizations engenders a serious fire risk.

During the coaching sessions, after expressing an initial reluctance to engage with the standards, personnel were pleasantly surprised to discover that it was easy to understand and follow the standards once they had been clarified. The attitude changed from confusion and reluctance to deal with standards, to optimism and enthusiasm. There was a marked difference in the expressed confidence of the personnel leaving the coaching sessions. The fear of failing to understand standards was dissipated.

5.6.2 The need to rephrase the standards

Many organizations have written papers explaining these standards using "normal" everyday language. However, no organization has produced work procedures to be used in maintenance departments based on these standards explained in normal language. These types of work procedures should be phrased so that they may be understood by all personnel in all maintenance professions, whether they are 'in-house' working for the organization or outsourced. These work procedures including the clearly explained standards should be included in guides outlining work procedures for maintenance departments and in general organizational work manuals. This would allow the crucial information from standards to be included in daily work guidelines. These guidelines quoting sections from standards should

be followed in order to fulfil official demands from insurance agencies, local authorities, and any government inspecting authorities (this topic is problematic in Israel, as although the position officially exists, no people are employed to fill the position). As the standards themselves are very long, they are often ignored, with maintenance personnel doing jobs the way they were originally taught to do them. This has led to problems occurring when the technology has changed, and these traditional work methods are no longer safe.

A good example of the need to "rephrase' standards is found in the standard for waste handling. This standard is divided in 32 parts, each part dealing with the storage and disposal of a specific type of waste. According to these guidelines, each type of waste has to be handled differently, using different types of containers. During the 'explaining and rephasing' phase, the 32 separate parts were reorganized into four sections. Each section described one handling method that could be used for the various kinds of waste specified in the new section. This simplification explained in coaching sessions enabled personnel to have confidence in incorporating the information from the standards in their work guidelines. It was found later, that in official environmental legislation, the methods for dealing with different waste products are grouped in this way, proving that the official government personnel also concluded that the instructions could be simplified in exactly the same way.

A further example is seen in relation to the lifts, escalators and moving walks that were installed and maintained in all the organizations where the research was conducted. According to the European Lift Association report, (2015), the number of accidents related to lifts, escalators and moving walkways between 2000 and 2015 increased for many reasons, but essentially due to the increases in the number of installations during this period. The increase in incidents also took place at the time when new standards were introduced, namely the new European standard EN 115-2:2010 in 1995 and then its revision in 2010. This standard covers the safety issues in installation and maintenance of lifts, escalators and moving walkways. This standard also cites 23 other standards describing specific parts necessary for fulfilling the requirements of Standard EN 115-2:2010. Throughout the entire research, not one organization was found where personnel were familiar with Standard EN 115-2:2010. Obviously, none of its components were known. Also no one was familiar with any of the other Standards cited within Standard EN 115-2:2010.

In one last example, in the Standard for describing the required treatment of hot water in health care organizations, there is a directive to measure five distinct temperatures. However, the instructions about the measuring device to be used (electromechanical or other) and where to place the thermometer or other devices for measuring these temperatures are unclear. There should be separate sets of instructions for separate devices, but these are lacking. As a result of unclear directions, the hot water temperature may not be measured accurately. At one blood donation centre, the temperature of the water in one of the machines during its cleaning loops, was too hot. The hot temperature caused the blood to coagulate, and instead of cleaning the machines, the clotted blood clogged the drainage system up. The water temperature was measured at various points and gave readings which were correct, but the readings did not reflect the temperature of the water in the pipes by the blood dialysis machines. The cleaning process failed and the drain system became contaminated. When inspecting the cleaning cycle, it was found that the hot water system was measured by wrongly placed sensors. When describing where the sensors should be placed, the units were given in inches not millimetres. Secondly, the temperature to set the sensor to, was given in Fahrenheit rather than Celsius. However, in the installation and maintenance manual the measurement units are in millimetres and degree Celsius. This resulted in incorrect placement of the sensors and incorrect interpretation of temperature readings. During the second research cycle a "rephrased" document was supplied in which the units matched the units used by the maintenance teams. The correct placement of the sensors was explained in simple language, so that all maintenance workers could check the temperature reading and the proper placement of the sensor. Although I discovered this example through my consultancy work and not during the research, I was able to use it with great effect in the coaching sessions. As soon as employees had a concrete example, those who took part in the coaching sessions were able to use this to explain the importance of properly understanding standards to other employees.

This illustrates the vital importance of including clearly phrased explanations of standards in work guidelines, that must be issued before work commences on any maintenance projects. I made a breakthrough when reading work guidelines on one of the sites of a pharmaceutical company my consultancy worked with, but which was later unwilling to participate in the full research. While checking the work guidelines for a project, I found that short extracts of the American National Standards Institute (ANSI/NFPA) were included in the guideline, without going into the complexity found within the whole standard. The short extracts were explained

clearly in simple language. Additional citations were also given, directing the workforce to relevant sections of the standard needed for the completion of a particular job. This became the main way I introduced standards in the coaching sessions.

In these coaching sessions it became evident that when rephrased information explaining the standards in the TOSSREM in simple clear language were presented to maintenance professionals they became much happier to engage with them. The rephrasing included citations expressed in simple language. The aim was that these would be included in work guidelines, directing the workforce to relevant sections of the standard needed for the completion of a particular job, thus respecting restrictions about quoting Standards without adding the exact citation.

This idea eventually became the template for all the selected sections of cited Standards. This methodology, guided by analytic hierarchy process (AHP) decision making, as described by Saaty (2012) leads to simple use of complex standard parts, rigorously described in plain and comprehensive language (see section 4.5.1). Details of certain sections of the standards are presented, alongside an intelligent use of citations directing users to the relevant sections of the actual standards. This avoids readers being deterred by an overload of detail and complexity. Apart from simplifying the access to the standards, it was also important that the explanatory material only used terms that would be familiar to the workforce. This included simple, precise instructions, only including the units used locally.

5.6.3 Examples of interactive coaching sessions following interviews.

5.6.3.1 At a multi-story geriatric health-care centre

Five accidents had occurred in a short time interval while taking patients to higher floors in elevators that are defined as being suitable for transporting patients at the geriatric centre with which included a dialysis department. The accidents were caused either by the elevators coming to a sudden halt, or by a sudden decrease in their speed. Investigations performed by the insurance company, concluded that there had not been proper maintenance of the elevators. This was their stated cause of the accidents. However, there was no mention of standards in the insurance companies' accident investigation reports.

<u>Interviews</u>

During the interviews carried out with personnel from the maintenance department responsible for this centre, I was told by the maintenance people that they carried out the maintenance procedures according to the work procedure guidelines held in the centre. In these work procedures, various standards relating to elevator maintenance were cited. However, during the interviews, the maintenance personnel explained that they did not know about the specific standards for elevators at medical centres. The guidelines on the site included the regulations for elevators in public buildings, rather than elevators in medical centres. When asked why these (inappropriate) standards were used, the answers indicated that they were supplied by the safety officer on the site. They added that as the standards for elevators fitting the definitions of those on the site were not clear, it was decided to follow regulations from other standards that they did understand. In the end, the work guidelines were based on a combination of standards for elevators for public buildings and elevators for a variety of uses. In answer to the question why these standards had been chosen, it was explained that they were familiar to the safety officer, and as no one could explain the differences between those standards and others for medical facilities in standards, he chose to follow those standards. Furthermore, it became clear to me that the location of the elevators had been decided by an estimate reviewer from the insurance company, without considering standards.

The differences between standards for the different types of use of the elevators are listed in the standard references, without going into detail in the main text. In the study undertaken by my research team, eight differences were found in the requirements for the maintenance for elevators in medical sites from those in general public sites. Three of these are critical for proper functioning of elevators in these sites. The elevator company was not aware of these three critical differences in standards for use in medical centres. They did not add the correct instructions and definitions for medical centres to the elevators' maintenance procedures. If these different standards had been applied, they would have prevented the accidents.

Coaching

In preparation for the coaching process, I reformulated the points required by standards for elevators in health care facilities. During coaching, it became quickly apparent that anyone present who had seen the standards in the way they had originally been formulated, had not understood which instructions applied to all the different types of sites where elevators are fitted. During the coaching session, participants were presented with the information from the

standards organized in a clear way. The clarified instructions explained exactly which standards applied to elevators in different settings. Throughout role play, all participants were easily capable of explaining what extra tasks needed to be carried out in elevators in health care centres. Information that had been inaccessible to the professionals, was clearly understood once it was presented to them in an organized fashion. In At the end of the coaching, the participants asked why no-one had explained this to them sooner.

5.6.3.2 Coaching at a hotel following an investigation into a fire and interviews.

An accident which had taken place in a hotel was used as an example for a coaching session. The accident took place a special event held at the hotel. During the preparation for the event, the hotel maintenance team had been involved in creating a new decorative backdrop. While the event was taking place, this backdrop caught fire. The fire caused burns to some of the staff who had been operating the décor as well as to a number of guests. In addition to the physical injuries the accident caused great mental anguish to the event's sponsors.

In the investigation of the incident by the insurance company, the investigator concluded that it was the incorrect operation of systems included in the backdrop that caused the fire. There were no references to standards relating to backdrops, how to build backdrops, or how to place this particular type of backdrop during the event.

Interviews

During interviews held by research team, it was found that no one on the hotel's maintenance team who built the décor knew that there were defined standards relating to the set-up of backdrops for events. All of these standards are categorized in standards appertaining to theatres or other types of performances. In the standards categorized as appertaining to events, these standards for backdrops are not expressly stated. There are general references to the fact that other standards exist relating to the safety of events. In the ongoing analysis undertaken by the research team together with the hotel's maintenance team, several deficiencies were found in the construction of the backdrop and in the way it was placed at the site of the event. In addition to formulating these standards is so complex and cumbersome that even the research team has difficulty understanding them and preparing them for presentation during the workout that took place at the hotel.

Coaching

In preparation for the coaching session, clear explanations of the standards relating to the building and placement of backdrops at events were written. During role play using the clarified standards, no participants had any problem explaining to others exactly what should be done when building and placing backdrops, to prevent risks of fires. Once it was certain that the explanations were clearly understood, the clarified standards were carefully formulated to add to the hotel's work procedures.

5.6.3.3 Coaching at a shopping mall following a fire, and an accident investigation.

Interviews

An example of the need for new Standards developing in changing situations is found in one of the largest shopping malls in Israel, where the fast-food areas were installed on all four floors. This was the first mall with fast-food areas one above the other up to four levels. This led to a situation where the system of ventilation and evacuating smoke from cooking had to be built differently from other existing sites, with all their fast-food venues concentrated in one floor/area. The standards for these smoke evacuation systems were new and extremely unclear – relating to several different groups of Standards: The Standard for the smoke piping was formulated according to NFPA 10, but had remarks attached to it requiring compliance to UL 300. The Standard for the smoke evacuation fans and their electrical installation systems was NFPA 70. Finally, the whole system has to comply with NFPA 72. All of these sections were specified as being required in only 28 different States in America. Standards applying to other geographical locations mentioned the systems in general, but did not list which extra Standards apply.

A fire broke out in this shopping centre. After this fire, the installation of the systems for smoke evacuation was checked. by an insurance inspector. The inspector found more instances of non-compliance with the Standards than compliance. The principal researcher was asked to investigate how come this kind of event could happen, as the system is maintained and inspected regularly. The research finding during interviews was that none of the professionals involved in the local design, installation and inspections were familiar with all of the required Standards.

Coaching

Following a coaching session conducted in this specific shopping centre, and the explanation of the Standards that need to be followed, in clearly phrased language, including all of the necessary phases of installation, the system had to be taken out. The whole smoke evacuation system had to be revised and adapted to the Standards' requirements. Some of the professional personnel from this mall are now serving as instructors at other sites in which these systems are installed. The coaching session gave the personnel a clear understanding of the standards, and the confidence to teach these standards to others.

5.7 Summary of Findings

The findings of this multi-grounded action research study can be summarized in accordance with the three phases of the study. In the first phase of this study based on a survey of accident reports relating to accidents associated with maintenance work, a link had been established between the high incidence of accidents related to maintenance work and the lack of implementation of standards by maintenance departments conducting the work. The grounded research interviews then demonstrated the extent to which safety standards are unknown, misunderstood or ignored in SME maintenance departments in Israel. The third stage of the action research carried out by interactive coaching demonstrated that change may be effected when personnel are actively involved in research studies and may consider themselves as part of the solution rather than as part of the problem.

The research is only the beginning of bringing about change that will reduce accidents related to maintenance work. One important step which has begun resulting from cooperation between the research team, management of maintenance departments and maintenance personnel is that information from complex standards has been written in concise, accessible formats that can be included in maintenance work guidelines. It was found that interactive coaching sessions provided excellent frameworks for assessment of the suggested wording of documents to be included in work guidelines, both in terms of including all essential information and in terms of being easily understood by maintenance personnel.

Chapter 6 – Discussion and Conclusions

6.1 Discussion

Since the opening of my consultancy, I had been confronted with an antagonising fact: the number of on-site accidents related to maintenance work was still growing, while more and more standards designed to improve work safety continued to be published. Being involved in many investigations into accidents related to maintenance work, and being confronted by these contradictions resulting in increasing number of events ignited my will to study, understand and if possibly help in providing solutions to these issues.
I started this research by studying past accidents reports, then carrying out on site interviews with maintenance personnel as part of MGAR intended to understand why these events are still taking place and attempting to bring about remedies.

My main motivation behind this research was derived from my desire to combat the increase in the number of on-site accidents involving maintenance personnel in SMEs in Israel over the last two decades. Two aspects of working practices in maintenance departments were studied. Firstly, the lack of incorporation of safety standards in work procedures and as a result of this, secondly, the lack of implementation of these standards in maintenance work carried out, which in turn causes accidents.

As discussed in the introduction to this study, when looking at complexity of published standards it quickly becomes apparent, if thought is given to the matter, that their complex formulation may make the standards inaccessible to many people. Furthermore, having different collections of safety standards in different geographic locations, further complicates the issue, particularly when imported devices are used. International companies want to abide by safety standards, yet may face different regulations in different parts of the worlds, using different units of measurement and referring to sub sections published in various other standards manuals. However, even in one single geographical location the great range of topics covered by standards, and the way in which they are published, means that it may be hard to find the relevant information. Furthermore, as pointed out in the introduction, maintenance departments may not always be able to protect the public who may be unaware of the dangers involved in using various systems, and accidents may occur even if standards are followed, as safety standards are only directed to what may be considered normal use.

However, this research was focussed on preventing avoidable accidents by making sure that standards are understood and incorporated into maintenance work procedure guidelines. My initial observations had indicated that there was often a lack of compatibility between safety standards and the work guidelines used on a daily basis in maintenance departments.

The first critically important decision in the study, however, was to undertake MGAR, which would collect qualitative rather than quantitative data, giving a richer picture of what was taking place on the ground, indicating why accidents were occurring, and then bring about change on the ground. The central idea behind this MGAR study, which evolved with time though an in-depth study of the standards relevant to maintenance work, and through interviews with maintenance personal, was that in order for safety standards to be taken on board by maintenance personnel, they need to be presented in an accessible manner. The idea was developed and put into practice by working with maintenance team leaders in interactive coaching sessions. The main research goals were, therefore, to improve the safety of maintenance work carried out by SMEs participating in the action research, through their participation in customized coaching sessions presenting, clarifying and explaining relevant standards to the maintenance department personnel. The ultimate goal of the research is to promote the inclusion of clarified extracts from standards in all SME maintenance department work guidelines, thus enabling their use in work procedures, so reducing the rate of preventable accidents in the future.

6.1.1 Maintenance department management

During the early stages of the research, it had been found that the classical issues studied in relation to SME maintenance management were costs, and more particularly, reducing operating costs (Alsyouf, 2009; Campbell & Reyes-Picknell, 2016; Kelly, 1997). There was some mention of safety and accident prevention during maintenance work (Lind, 2009) or inadequate maintenance work (Holmgren, 2006). Some researchers did also extend their field of research into critical success factors, work efficiency, performance indicators (De Groote, 1995; Swanson, 2001), benchmarking (Chan, 2008; Wireman, 2004), maintenance strategies including outsourcing or in-house maintenance (Assaf et.al., 2011; Bertolini et al., 2004; Suweero, & Moungnoi, 2016) but all of them in the end converged to concentrating on costs and the reduction of operating costs.

By contrast, in this study, the focus was on the inclusion of standards in work procedures. It could have been supposed that standards are not followed due to cost issues. However, in literature even dealing with maintenance strategies and work procedures (Bonde, & Fulzele, 2013; Campbell & Reyes-Picknell, 2015; Carnero & Gonzalez-Prida, 2017) the inappropriate or non-existent inclusion of standards in work procedures was not related to costs, it was usually simply ignored.

The issues this research focusses on: the inclusion of safety, energy efficiency and environmental preservation and risk assessment standards when composing work plans and guidelines in SMEs maintenance departments, were not found in the literature. From the preliminary interviews, it immediately became clear that the answers received were presenting a very different picture of the way that maintenance departments function, to that described in any previous studies. The open-ended questions, as hoped, did indeed yield a fuller picture of what was happening on the ground than could have been obtained from closed questions in a completely quantitative study.

Through my initial reading for this study, I became aware of various theories of KM within organizations, notably Nonaka and Takeuchi's SECI model. It became clear to me, that even if some members of an organization did possess the crucial knowledge on standards that could prevent accidents, there was a breakdown in the transfer of this knowledge to those carrying out maintenance tasks in practice. That is to say that knowledge held within an organization was not completing the stages of socialization, externalization, combination and internalization of that knowledge. I also became cognizant of the concepts involved in organizational learning and knowing in practice. I realized that a combination of investigation with active interventions would be needed in order to effect a change in the way organizational learning was taking place with regards to standards. In order for maintenance department management to agree to personnel taking part in active learning through interactive coaching sessions, I had to use terminology familiar to them from TQM. It was only when management agreed to participate with coaching programmes that I could make provocative use of organizational learning theories to encourage reluctant personnel to engage with standards and accept their importance. The internalization of this knowledge creates a new approach to including critical information from standards into work guidelines, once that information is phrased in a clear way.

6.1.2 Standards

During the early stages of the research, the focus had been on selecting the standards and regulations specified in accident investigation reports, insurance reports and other documents written by authorities involved with inspecting maintenance work. This process was begun after a special parliamentary commission conducted an investigation into accidents related to maintenance work, and focussed attention on the accidents and on the reports.

While drawing up lists of standards cited in the reports, the interviewer read the standards, and other sections of standards they referred to. The first stage of the study culminated in the construction of the TOSSREM, the table of standards relevant to maintenance work. The TOSSREM was compiled from the several hundred sections of standards cited in the reports read, and included standards in the fields of safety, risk assessment, and energy conservation and environmental protection. Energy conservation and environmental protection are deemed important for sustainability and were thought to add to the social impact of the study and were therefore included. After collating the table, my first realization was that I needed to reach a proper understanding of all of these standards, especially those that were not familiar.

On reading all of these standards closely, it became increasingly obvious that the standards are formulated using complex technical terms. Furthermore, even if the terms are understood, there appeared to be internal contradictions in the regulations. One standard may cite another one which may, on first reading, appear to give conflicting instructions. This leads to situations wherein even If the words are understood, the instructions may easily be misunderstood. There also seemed to be many instances of generalized instructions which do not apply to particular cases, but the definitions of the cases which they do or do not apply to was unclear.

The obtuse character of the standards gave the clue needed to solve why standards are not implemented in maintenance work. Knowing the two answers that standards are not implemented in maintenance departments and that standards are written in a way that is almost completely incomprehensible, the double loop reverse engineering process was fairly simple. We knew *what* was happening on the ground, i.e., that accidents were happening because standards were not implemented. When the interviews with maintenance personnel were constructed to allow personnel to explain why this was happening, the picture was complete. Standards were not implemented because people writing work procedures do not

understand the standards. The emphasis of the research gradually moved towards assessing which standards are misunderstood, rather than just evaluating which standards are implemented.

6.1.3 Interviews

As I was part of the consulting bodies advising these SMEs it was then a straight forward procedure to collate tables of the standards' sections from the TOSSREM that are relevant to particular professionals working in the maintenance departments

After the survey of documents and collation of the tables, I conducted on site face to face interviews in which he verified the level of knowledge and implementation of the standards in the TOSSREM. After starting the interviews, it was quickly discovered that there were very low rates of implementation of the standards, the focus of the study moved to finding why that was. On including questions designed to discover whether maintenance personnel understood the standards, it was found that standards are often ignored as they considered too complicated to understand. From this point on, action research was undertaken with rephrased extracts of the standards being offered as supplementary material to the interviews. This brought about a gradual transition from negative to positive attitudes towards working with standards.

Despite the fact that the findings in initial interviews with maintenance personnel were expected, as they represent one of the core issues of this research, the level of ignorance and lack of understanding were surprising. This situation in the field meant that an extra process became part of the MGAR, which had not been planned from the beginning. This process focussed on the complex language of the Standards. Whether the language and wording of the Standards was understood or not is a different topic to whether the technical content of the Standard is understood. The interviews needed to ascertain whether the wording of the Standards- the language used – was understood. It was decided that the information needed to be explained in clear language. Whether or not the new wording was understood was then verified in coaching sessions, which continued until it was certain that the wording could be readily understood by all professionals who needed to comply with the information.

Following the findings obtained, certain terminologies used in standards were excluded as these terms were not clear to the maintenance professionals. Once the language was clearly, it

was expected that work procedures using this simplified language would be complied with. While asking interviewees about ISO 31000 (Risk assessment / management) it was found that there was a high level of confusion between different terminologies describing the analysis and evaluation of the risks. This confusion resulted in incorrect descriptions of actions which had to be carried out to ensure safety. One of the descriptions concerns the duties given to each member of the working team. In the description, the leading professional is described in one place as the process stakeholder and in another place as the "interested party". Furthermore, the terms "likelihood" and "probability", are used interchangeably, but a note declaring that there is a comprehensive difference in the way these terms are used in local languages was added. However, no alternative to any of these words is supplied, keeping the contextual value of the description of the team leader.
It had been surprising to discover that there was no correlation between the education of interviewees and their comprehension of essential standards. Engineers did not demonstrate better comprehension of standards than interviewees who did not have advanced training and did not hold academic degrees. Chemical engineers and electrical engineers often were not aware of standards which were supposed to dictate various aspects of their work.

Some further clues were found in the interviews as to how to move forward with action research, which would start to introduce change into the maintenance departments. One early finding indicated that the scope of the standards is explained in reference chapters, separate from the main body of the text. People reading the standards need to access this information. The correct information needs to be extracted from the standards for each type of organization and inserted into their work procedures. Another early finding was that when coaching sessions are held, explaining the complex information from standards in simple terms, this information can be included in work procedures. These simple explanations need to be easily accessible to all personnel writing or using procedural guideline.

Nearly all of the interviewees stated that they were incapable of incorporating or using standards, which they do not fully understand, in their work procedures. The answers received in interviews held in a variety of different organizations, with people holding different positions, having undergone different types and working in different professions were not related to the type of organization, the person's professional training, their job description, salary differences or other economic issues. In this way, the study immediately gave indications of a discrepancy with previous study proposals in Israel, which had always

concerned themselves with financial considerations. The reality the research found had little connection with economics. The problem of not understanding standards and regulations quickly became a dominant theme. Moreover, many interviewees stated that they prefer to knowingly ignore a standard / regulation they don't understand, rather than include or quote it in work guidelines, as they are uncertain whether they will know how to fulfil the regulations. This was found to be the case, even if by doing this they are taking avoidable risks. The answers given by professionals with different levels of qualifications, from technicians or general workers to engineers, were very similar. Education, professional training and experience seemed to have no influence.

6.1.4 Coaching

The next step of the action research involved interactive coaching sessions during which role plays and questions and answer sessions helped ensure that the rephrased information from standards was formulated in the clearest way possible, and allowed the rephrased information to be shared with maintenance team leaders and other maintenance professionals. Despite being more complex to prepare, the coaching concept was chosen instead of lectures, as it was expected to be more efficient in inducing an active learning process. This was found to be the case in practice. While initially, negative attitudes had been expressed towards standards by maintenance personnel, and academics had thought the research goals were unattainable, as maintenance professionals simply would not or could not engage with standards, the opposite was found to be the case. Following coaching sessions, none of the participating personnel expressed disrespect or rejection of the standards. Many explained that they had not been able to include the information in work guidelines in the past when explicit explanations of the relevance of the standards and how they should include them in their guidelines, had not been offered. From both the interviews and the coaching sessions it was obvious that the professional personnel in the SMEs was thirsty for knowledge that could help improve the safety of their work, when offered in clear ways ensuring all the information was accessible to them.

6.2 Actionable knowledge and insights from the research process

Many valuable lessons were learnt during the action research conducted for this DBA over and above the theoretical knowledge gained on past studies and the results of the research

itself. First and foremost, in the business world, effecting change is dependent on good communications. However, formulating clearly what you want to say is only the one half of the equation. In order to engage with business professionals, one also has to develop good listening skills and find ways of asking questions which will elicit honest and extensive answers. Furthermore, from the start of the research I leant that it was essential to keep an open mind. Even when there are pervasive attitudes which create foregone conclusions, it is still worthwhile challenging these. In the case of this study, the pervasive wisdom held that maintenance professionals simply cannot or do not wish to follow standards. Nobody had taken the time to consider that there may be an underlying reason for this. Furthermore, studies into maintenance management had predominantly addressed financial matters or department structure and outsourcing. It was necessary to 'break the mould' and head off in a completely new direction to make progress towards promoting safety by explaining complex standards.

My personal contribution to the study has been described throughout this thesis, from the earliest review of accident reports and investigations into incidents occurring related to maintenance work, and my survey of published safety standards, to my development of a MGAR design for the study; conducting interviews on the ground with maintenance personnel and planning and carrying out interactive coaching sessions. One of the strongest points of the research design was the close involvement with maintenance team leaders. This enabled a kind of chain reaction effect, whereby maintenance team leaders who include critical information from standards in their department's work guidelines, and see a reduction in accidents as a result of this, can pass on their newly positive attitudes to other colleagues.

On the other hand, this expected long term effect is also a limitation to the study. The ultimate aim of the action research is a reduction in accidents related to maintenance work conducted in SMEs. This long-term effect is not quantifiable at present, and will not be demonstrated for some time. To some extent a leap of faith is required to persuade SME management to engage in the process of coaching sessions and rewriting their work guidelines in line with standards. Nevertheless, the study also generated tools that will be useful in extending the MGAR into other organizations and into other areas of the world. The TOSSREM found in annex 2, and rephrased segments of standards are both useful tools for maintenance professionals and scholars interested in safety issues in maintenance work alike.

The main method of the using open ended questions yielding descriptive answers, may be considered less convincing than some quantitative studies. Although answers were tabulated using fuzzy sets, this again differs from quantitative studies supported by statistical analyses. However, it must be said, that it was only by asking open-ended questions that the real picture of how work is conducted in maintenance departments was revealed. Beyond this, when attitudes were fully explained, a way was found to overcome the problems that had prevented the implementation of important standards in maintenance work.

One of the reasons why it was so important for me to take part in the DBA program was that I wished to ensure that the safety issues plaguing maintenance departments would attract more attention and, in particular, the novel method I devised for introducing safety standards into maintenance department guidelines could be implemented more widely. The overall aim has always been to improve safety and reduce accidents.

The completion of the DBA program will allow the presentation of the methods developed in this study to organizations around the world, including established medical institutions and government bodies who are interested in new concepts of safety management, which have an academic basis. These organizations may then promote the inclusion of safety standards in work guidelines, in the ways explained here, using rephrased segments of standards that are comprehensible to all personnel. Many of these organizations would not consider adopting new approaches that have no grounding in academia.

This study also reinforces my stance that methods used in the past were not effective in improving safety records in SME maintenance departments. Despite data clearly indicating that methods such as outsourcing or benchmarking had no effect on improving safety, no new concepts have been adopted in the industry or in scholarship. It is my hope that the completion of the DBA will enable the methods outlined here for the inclusion of safety standards, in an accessible manner, into work guidelines to be introduced into further studies and into organizations around the world.

Mainly, actually, I see that my developed concept for contours enabling a surround to the hurdles of the contradictions between imposed rules requirements described in standards and legal requirements gathered during the research and the existing work methodologies could be and are added to organizational work methodologies. These contours built and based on described known methodologies included in my double loop studied issues approached in my learnings and findings presented in our rich pictures, developed during coaching sessions

based on gathered data, are contours acceptable by all involved sides and feasible to be introduced in work concepts, thus enabling reduction of accidents in work places.

6.3 Conclusions

The research programs led to three main conclusions. Firstly, professionals in organizational maintenance departments do not wish to purposely avoid implementing and adhering to Standards. They do not implement the regulations included in the standards because they do not understand them. The noncompliance with safety standards leads to a situation where personnel and the general public are exposed to dangers at the time of maintenance work. It is important to emphasize, that in all maintenance departments involved in the research, when standards were understood, there was a strong motivation to implement all of the safety standards and to include them in their procedural guidelines. This was immediately noticed once rephrased standards were presented to personnel.

The action research in the study included coaching sessions with maintenance personnel. These were different to training sessions held in these organizations in the past, which were based on very skilled professionals presenting the standards and explaining them in lectures. These lectures did not allow any interaction between the lecturers and the personnel. No questions were asked, and the personnel did not understand the material after the lectures. Furthermore, as there was not time for questions, site specific issues were not brought up in these lectures, so specific problems within any given organization were not resolved. The coaching concept, relying on open dialog and research, together with the novel reverse double loop method enabled for the first time, comprehensive understanding of the specific issues presented in the Standards which previously had been unclear. The re-phrasing of the complex Standards' sections and verbal explanations clarifying general issues. There was also time specifically directed to the difficulties and failures within each particular organization, as revealed through the research. The role play in the coaching sessions allowed personnel to gain confidence in their comprehension of the standards, and in their ability to explain them clearly to others. The time allowed for discussions, allowed all those present to become confident in their knowledge.

The reverse double loop method, starting with incident reports, which are the result of a problematic situation resulting from standards not being implemented, and working back to discover which standards are not being followed and why that is, enables an ongoing resolution of the problem. Continued professional coaching processes within the organizations can be aimed at clarifying exactly those issues which are causing accidents. Following the on-site interviews, the coaching can be customized for each organization. It was seen that some issues concern specific sites more than others, but some were widely spread through all of the maintenance departments. The change in attitudes to standards resulting from the coaching sessions helped promote the wish amongst organizations to continue and even expand the coaching process to more cover more issues. The findings thus promote a conviction that this double loop method is effective, and raises the organizations' commitments to safety. Organizations have expressed the wish to adopt the process to issues not contained in Standards, related to all maintenance aspects essentially related to safety but also improvements in general maintenance work procedures.

Today the action research is concentrating its efforts in properly formulating the organizational maintenance work procedures, so that they comply with the required components from the Standards. It is also further developing the best way to insert the reformulated information into coaching sessions conducted in organizations in regular periods. Local regulations combined with insurance requirements now demand that each year, with the renewal of insurance policies, there will be a ratification of the organizational work procedures. This ratification has to include acknowledgement of renewed Standards and how these additions are included in procedure updates.

In conclusion, following this research it is possible to say that the lack of knowledge, or even ignorance, of standards and regulations results in improper or non-existent work procedures. This in turn leads to the increase in unnecessary and avoidable occupational accidents. Previous studies concerning accidents in work environments concluded that there is a need for improving the quality of workmanship or suggested that salary augmentations would resolve the problems. These, essentially, were the only areas looked at leading to pre-determined conclusions of the studies. In this research I found that it was the lack of comprehension of standards, regulations and work procedures that has generated the increase in accidents. Furthermore, the action research indicates that interactive coaching sessions explaining rephrased standards may be a useful method to combat this lack of comprehension, and so reduce accidents related to inadequate maintenance work.

Annex 1.

Preliminary Interview:

1. What is its primary purpose of the organization?
2. How large is it?
3. How efficient is the company?
4. What technologies are in use?
5. Are there any more efficient systems available?
6. How well are the staff members doing their jobs?
7. Are the duties distributed effectively?
8. Is there a need to hire more people, or to downsize?
9. Briefly describe the maintenance department and its functions.
10. How many people are on staff of the maintenance department?
11. How many hours per week do they work?
12. Are any outsourcing bodies employed?
13. Are there any seasonal or other peaks that affect the work volume?
14. Would it be more efficient to outsource any of the work?
15. Alternatively, would it be better to cease outsourcing and perform that work in-house?
16. Are there other known and recognized functions that are interdependent of the maintenance department? Include a short description of the processes affected.
17. Are there specific demands in standards and regulations with regard to specific personnel presence on site at specific times or occurrences?
18. How are the demands of standards and regulations that are legally imposed on the organization?
19. Are all of these standards and regulations recognized by the organization and listed in detail in such a way that they are clearly understood by all organizational personnel?
20. What is the level of awareness of standards and regulations in the organization?
21. What is the level of understanding of these standards and regulations amongst the personnel and how it is implemented in existing organizational procedures?
22. Are these standards included in daily work procedures?

23. Are instructions given and explained in organizational training and coaching sessions**?**
24. What is your opinion on how standard implementation is supervised by professional inspectors?
25. Can you describe corrective measures and actions taken after failures are detected?
26. Can you explain how the regulations influence the selection of personnel?
27. According to the division of the standards into three main groups: professional safety; energy efficiency and environmental preservation and overall risk assessment standards which ones are the least and the most integrated into organizational work procedures, what is the level of understanding amongst the department personnel?

Annex 2

The list of Standards - TOSSREM

Standards Relevant to the Safety of Maintenance Work

IEC/TR 61000-1-1	Electromagnetic compatibility (EMC) - Part 1: General - Section 1: Application and interpretation of fundamental definitions and terms
IEC/TR 61000-2-1	Electromagnetic compatibility (EMC) - Part 2: Environment - Section 1: Description of the environment - Electromagnetic environment for low-frequency conducted disturbances and signalling in public power supply systems
IEC/TS 61000-2-5	Electromagnetic compatibility (EMC) - Part 2: Environment - Section 5: Classification of electromagnetic environments. Basic EMC publication
IEC 61000-3-3	Electromagnetic compatibility (EMC) – Part 3-3: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤ 16 A per phase and not subject to conditional connection
IEC/TR 61000-1-4	Electromagnetic compatibility (EMC) – Parts 1-4: General - Historical rationale for the limitation of power-frequency conducted harmonic current emissions from equipment, in the frequency range up to 2 kHz
IEC/TR 61000-1-5	Electromagnetic compatibility (EMC) - Part 1-5: General - High power electromagnetic (HPEM) effects on civil systems
IEC 61000-2-2	Electromagnetic compatibility (EMC) - Part 2-2: Environment - Compatibility levels for low-frequency conducted disturbances and signalling in public low-voltage power supply systems
IEC 61000-2-4	Electromagnetic compatibility (EMC) - Part 2-4: Environment - Compatibility levels in industrial plants for low-frequency conducted disturbances
IEC/TR 61000-2-8	Electromagnetic compatibility (EMC) - Part 2-8: Environment - Voltage dips and short interruptions on public electric power supply systems with statistical measurement results
IEC 61000-2-9	Electromagnetic compatibility (EMC) - Part 2-8: Environment - Voltage dips and short interruptions on public electric power supply systems with statistical measurement results
IEC 61000-2-10	Electromagnetic compatibility (EMC) - Part 2: Environment - Section 9: Description of HEMP environment - Radiated disturbance. Basic EMC publication
IEC 61000-2-11	Electromagnetic compatibility (EMC) - Part 2-11: Environment - Classification of HEMP environments
IEC 61000-2-12	Electromagnetic compatibility (EMC) - Part 2-12: Environment - Compatibility levels for low-frequency conducted disturbances and signalling in public medium-voltage power supply systems
IEC 61000-2-13	Electromagnetic compatibility (EMC) - Part 2-13: Environment - High-power electromagnetic (HPEM) environments - Radiated and conducted
IEC/TR 61000-2-14	Electromagnetic compatibility (EMC) - Part 2-14: Environment – Over-voltages on public electricity distribution networks
IEC 61000-3-2	Electromagnetic compatibility (EMC) - Part 3-2: Limits - Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)
IEC 61000-3-3	Electromagnetic compatibility (EMC) - Part 3-3: Limits - Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤ 16 A per phase and not subject to conditional connection
EN 50160	Voltage characteristics of electricity supplied by public distribution system

G5/4-1 – ENA	This standard specifies harmonic current emission limits. This standard identifies consumers by they point of common coupling to the supply and applies limits at that point. This standard applies to every consumer connected to the Public Electricity Supply.
IEEE Std 519	Recommended Practices and Requirements for Harmonics Control in Electrical Power Systems
IEEE 1159	Recommended Practice for Monitoring Electric Power Quality
IEC 62052-11	Electricity metering equipment (AC) - General requirements, tests and test conditions
IEC 62053-11	Electromechanical meters for active energy (classes 0,5, 1 and 2)
IEC 62053-21	Electricity metering equipment (a.c.) - Particular requirements - Part 21: Static meters for active energy (classes 1 and 2)
IEC 62053-22	Electricity metering equipment (a.c.) - Particular Requirements - Part 22: Static meters for active energy (classes 0,2 S and 0,5 S)
IEC 62053-23	Electricity metering equipment (a.c.) - Particular requirements - Part 23: Static meters for reactive energy (classes 2 and 3)

IEC 60050-131 , IEC 60050-161 , IEC 60065 , IEC 60107-1 , IEC 60155 , IEC 60268-3 , IEC 60335-2-2 , IEC 60335-2-7 , IEC 60335-2-14 , IEC 60974-1 , IEC 61000-2-2 , IEC 61000-4-7, IEC/TS 61000-3-4 , IEC 60050-131 , IEC 60050-161 , IEC 60065 , IEC 60107-1 , IEC 60155 , IEC 60268-3 , IEC 60335-2-2 , IEC 60335-2-7 , IEC 60335-2-14 , IEC 60974-1 , IEC 61000-2-2 , IEC 61000-4-7 , IEC 61000-3-4

ISO 31000	*Risk assessment management and techniques – Guidelines,* provides principles, framework and a process for managing risk. It can be used by any organization regardless of its size, activity or sector.
ISO 50006	Measuring Energy Performance using Energy Baselines and Energy Performance indicators – General Principles and Guidance.
BS EN115-1: 2008+A1: BS7801: 2008+A1:	Guidelines for the safe operation of escalators and moving walks
ISO 9001	Quality management
ISO 50001	Energy performance and management systems; gives organizations the requirements for energy management systems (EnMS); provides benefits for organizations large and small, in both public and private sectors, in manufacturing and services, in all regions of the world. will establish a framework for industrial plants; commercial, institutional, and governmental facilities; and entire organizations to manage energy. Targeting broad applicability across national economic sectors, it is estimated that the standard could influence up to 60 % of the world's energy use.
ISO 14001	Standard for environmental managements systems (EMS)

This list is a tool that may be also used in any future research into the implementation of standards in maintenance work.

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