Doctoral Dissertation
Doctoral Program in Energy Engineering (30th Cycle)

Criteria for improvement and dissemination of Occupational Safety and Health - OS&H Culture in critical NACE sectors

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Turin, April 27th, 2019

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Chapter 1

Introduction

1.1 OS&H Context

The analysis of the Occupational Safety and Health - OS&H injuries and Health impairments trends has been the cue to draw a realistic picture of a situation influenced by several hidden parameters often more numerous than the obvious ones. On the heel of the impressive progress of the technologies and the automation of some processes, there were positive results even in this field. Data available are hard to read at a first glance, and an in-depth understanding requires expert analyst: at first, it is necessary to make different considerations for injuries and Health impairments.

According to the widespread approach also enforced by the European regulations (namely 89/391 EEC Framework Directive and daughters), OS&H should be based on technical measures, organization and appropriate modus operandi. Furthermore, suggestions are available in the Safety-Quality approach standards (e.g. ISO 45001, ...).

This system constitutes the backbone chain of modern OS&H: in some scenarios, together with further implementation of special supplementary rules (e.g. the request for development of Safety and Health plans complying with the rules in case of temporary and mobile construction sites), it led substantial, especially cultural, gains. Injuries and Health impairments are not a fatalistically acceptable toll associated with the work activities, but they can and should be avoided. A proof that this is not a goal unattainable in the real world is that in the last decade a number of important and challenging underground works attained the zero death target throughout the entire work duration, in spite of the “traditional” rate of 1 fatality / km.

1.2 The data

According to the data provided by the European Agency for Safety and Health at Work (Harmonized data on accidents at work collected in the framework of the administrative data collection 'European Statistics on Accidents at Work (ESAW)), in the 28 EU Countries, the number of fatalities ranges from 3800 in 2009 and 3350 in 2014. The standard incidence rate (number of accidents occurred during the year, vs. the reference population expressed in 10^5 persons) varies from 2.52 to 2.32 in the same years. Between 2014 and 2015, there was a slight decrease in the total number of non-fatal accidents at work in the EU-28, some 9118 fewer (equivalent to a reduction of 0.3 %). By contrast, there were 102 additional fatal accidents at work in the EU-28 during 2015 when compared with a year before (equivalent to an increase of 2.7 % - Eurostat 2019)[1].

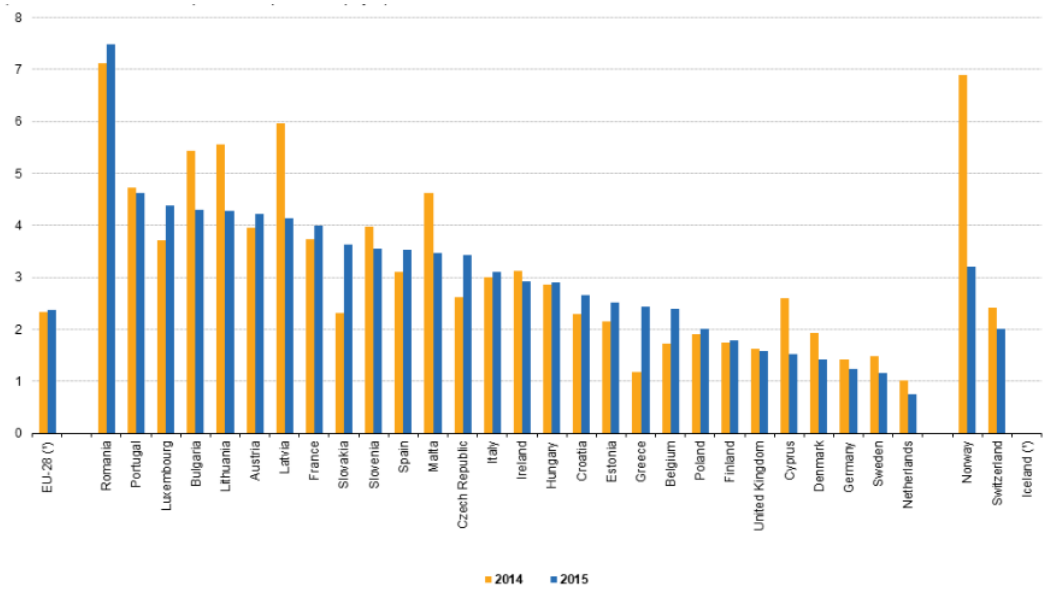


Figure 1 - Fatal accidents at work, 2014 and 2015 (standardised incidence rates per 100 000 persons employed) - source ESAW.

As to the Health aspects, the number of people reporting a work-related Health problem ranges from 35% (2007) to 47% (2013).

Even if the data are somehow approximated, and diversified among the EU Countries, such figures are impressive, even more since the average age of fatal

accident victims is 38÷40 years; given a life expectancy of approximately 78÷80 years, the yearly total loss due to work related accidents can be estimated in more than $1.3 \cdot 10^5$ year!

Moreover, the data available in statistical databases on work-related accidents and Health impairments show still high frequency indexes, with a not encouraging trend, particularly in some NACE sectors (for the French term “Nomenclature statistique des Activités Économiques dans la Communauté européenne”).

As described in Figure 2, the injuries’ trend in Italy has been following the general progress of the number of workers employed: there are peaks related to the economic boom, improvement phases strictly connected to the Italian enforcement of European regulations. In Figure 2 it is clear that the number of fatalities/years follows the industrial innovations, showing new scenarios in some cases predictable, but mostly unexpected.

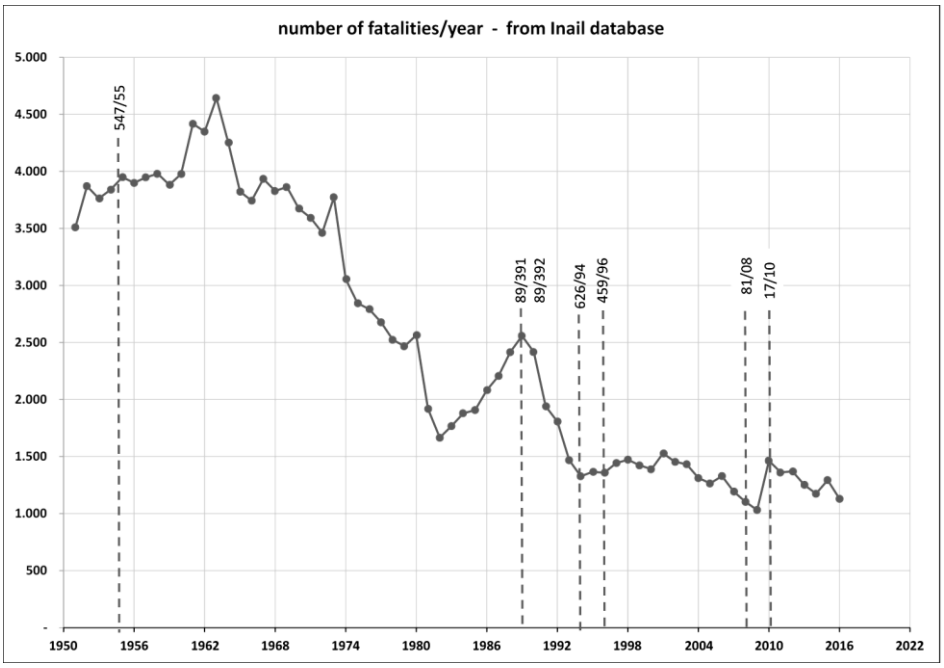


Figure 2 the Italian injuries' trend from 1950 to 2016

In Italy, an average value not far from 3 work related fatalities/day is still recorded, included the categories of workers not considered by the National Insurance Institute – Inail[i], despite the national enforcement since 1994 of the 89/391 European Directive on the introduction of measures to encourage improvements in the Safety and Health of workers.

The Occupational Diseases are not taken into account, more difficult to identify in the case of Health impairments due to the delay between the exposure time –and effects occurrence, i.e. lag period. In fact, the consequences of the underestimation of the criticality of overexposure conditions at workplaces - especially to chemical and carcinogenic pollutants – often are dramatically manifest when it is too late to effectively intervene.

1.3 The Data Interpretation

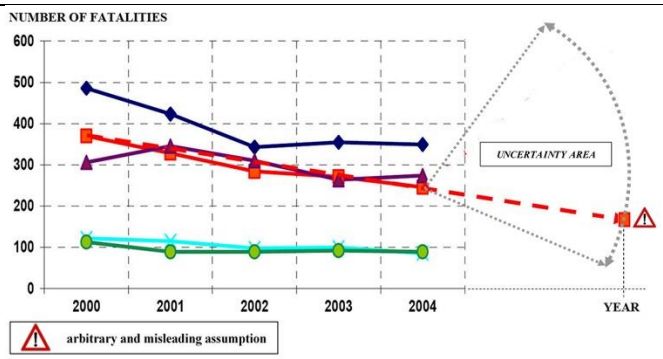
It is clear that the numbers found in National or International databases, if not contextualized are meaningless, and sometimes they can be confounders. To avoid this common error, the data collected in the OS&H context have been in depth analyzed and put in cause- consequence chains to better understand the reasons of their occurrence.

The statistical databases, even if based on the questionable Heinrich assumptions, can be a precious instrument for the prevention of work related accidents. Some databases evolved to include information on the violations of the Safety standards, which play a pivotal role for an exhaustive Risk Assessment (in absence of this datum only Attention Indexes can be inferred).

Accident databases can still be of help for prevention: accident analysis is a backward-looking process whereas making recommendations is forward looking. Therefore, the study of occurred accidents can be helpful to prevent identical accidents in identical scenarios (*Hopkins, 2014*).

The Attention Index - A.I., focusing the inspector's attention towards the more common direct causes of the event makes possible effective inspections.

However, some common errors and misuses lead to a biased forecasting of expectable accident rates, and thus to important distortions in the prevention action should be avoided, the most common being:



possible sets of errors due to:

- ✓ reduced statistical basis (region or even province, disregarding the local industrial situation);
- ✓ insufficient analysis of boundary data (e.g. economic situation);
- ✓ uncritical use of yearly data, sensitive to exceptional events, instead of packaged values.

Figure 3 - : misleading forecast of statistical trends

Data in general (and work-related accident data in our case) consist in the information collected along the investigation process. They are pieces of information either written, spoken, stored or symbolized, that can be used as a basis for making references or inferences, for an in-depth understanding of the chain of causes leading to each event, the final target being to correctly identify the preventive measures to implement in similar situations.

Data may be numerical (e.g. age of the worker involved, years of experience, number of lost days, etc.), consisting of values that can be numerically quantified, or non-numerical. Since the reports of investigation contain a large amount of information in the form of textual description, a series of attempts researchers tried to develop retrieval techniques, sometimes with odd results (e.g. from of unchecked use of automatic multiple word search programs). Obviously, the use of keywords can simplify the problem, each of them being subsequently associated to a numerical code, but a large quantity of information is inevitably lost: the full report can be available only in written lines/pages annexed to each form, but not automatically analyzed.

Thanks to the substantial evolution of the databases (e.g. United States Department of Labor - DOL OSH Agency), including information on the violations of the Safety standards, in some cases a careful analysis of technological modifications has made available useful correlations (*Camisassi et al., 2004, 2006*).

Anyhow, an unbiased understanding of the embedded causes (Root Causes) of the work-related accidents is certainly necessary. The CCCP (Computer-aided

Cause Consequence for Prevention) technique, an evolution from CCA - Cause-Consequence Analysis (itself a combination of FTA - Fault Tree Analysis & ETA – Event Tree Analysis) based on extensive investigation on the different approaches to the work-related accident analysis. The CCCP technique focuses on the in-depth examination of each accident, and its two-way approach made possible both a clear understanding of the Chain of Intermediate Events up to the Root Causes, and to verify and compare the expectable effectiveness of possible preventive measures.
The CCCP technique and software has been tested on several work-related accidents, analyzed to support Prosecutor Investigations in different NACE sectors, gaining interesting results, user friendly and, thanks to its System Approach, immune from errors due to subjective judgments or hasty evaluations.

The lack of information on the violations of Safety Standards, the consequent impossibility of a direct calculation of the accident Probability of Occurrence, and the misinterpretation of A.I. as a Risk Index lead directly to an incorrect Risk Assessment.
The CCCP technique in the final release (Figure 4, below), after evolution and tests (*Demichela et al, 2011- Luzzi et al, 2015*), can contribute to correctly understand the preconditions leading to the very Root Causes of work-related accidents. That task results important in particular in complex situations where the most serious criticalities are concealed, the Iceberg analogy common to clarify this concept- and in the definition of the preventive countermeasures.

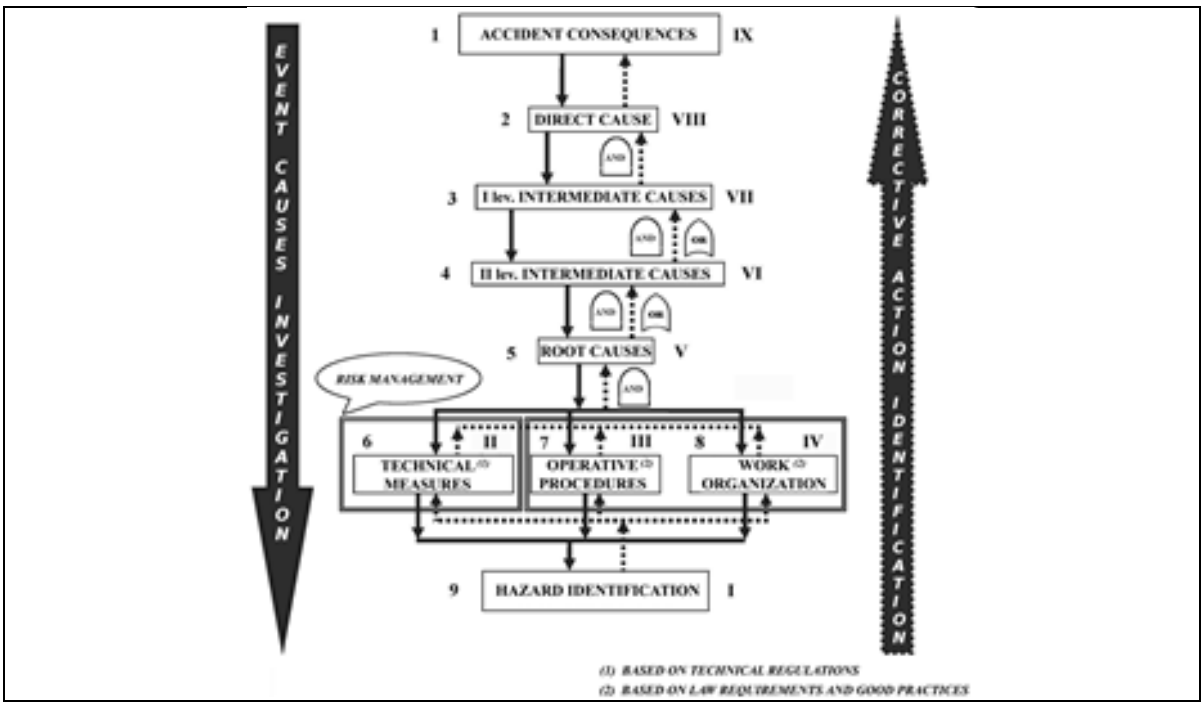


Figure 4 - home screen of the CCCP software (above) and flow chart of the accidents analysis two-way approach (below).

It is important to underline that the use of the statistical data on work related accidents is derived from the Heinrich (*1931*) approach, which suggests that prevention can be implemented based on information on the frequency of deviations from a correct working situation: this led to the development of very large databases on injuries and fatalities in many industrialized countries.

However, the Heinrich model is based on a "Person Approach" (the misconduct of victims or colleagues is the main cause of deviation, despite the obvious consideration that they and they only are in direct contact with the Hazard Factor): the resulting accident analysis is often incorrect, and useless for improvements of the Safety System. Therefore, the Heinrich model is not free from criticism (*Reason, 2000*), and in terms of representativeness of the input data (*Manuele, 2011*), and hence at least obsolete for the modern Safety science.

Instead, the CCCP software structure was of valuable aid, leaving the analyst always free to make independent decisions, since reduces the possibility of errors due to subjective judgment or hasty evaluation, and the too easy conclusion involving some victim's misbehavior.

1.4 Problem statement

Analyzing a large number of accidents emerged that the primary cause of the failure lays in the still widespread incapability to act according to the Occupational Culture of Safety and Health, logical before than regulated.

Some of the main causes of this situation are:

- the technological context, notwithstanding the important progress also in terms of Safety and Health,
- the changed socio-economic scenario,
- the more and more diversified composition and origin countries of the workforce,
- the difficulties in implementing preventive measures in complex and constantly evolving production situations.

Risk can be defined as the potential of losing something of value. The *Risk Assessment is the evaluation* -pivotal to define a correct prioritization of *Risk Management*- of the levels of risk involved in a situation, due to the associated hazards. A very careful *Hazard Factors Identification* and *Exposure Models* are therefore of utmost importance.

The *Risk Management* includes all the activities which give rise to the elimination or minimization of risks, through *Prevention* (i.e. technical, organizational or procedural steps to reduce -and possibly cancel- the expected frequency of occurrence or the contact factor), or *Protection* (general or personal), to mitigate the severity of the possible damage.

Table 1 - A brief but necessary resume and glossary – source De Cillis, 2017

Risk: potential of losing something of value - life, Health, property or environment can be compromised by a given action, activity or inaction involving a Hazard Factor causing the Unwanted Event, and expressed by means of the relationship
*RISK = M * P (predictable damage M due to the unwanted event × expected frequency of occurrence P)* where: $M = ED * FC * n$

ED = seriousness of the possible consequence (death, injuries and Health impairments, etc...);

FC = interference (contact factor): a function of the percentile exposure time to potentially hazardous operations or situations vs to the working cycle (common reference 8h/d);

n = number of exposed workers

$$RISK = ED * FC * P * n$$

As evidenced also by real cases, a large part of the OS&H criticalities are due to serious cultural deficiencies of all the parties involved from designers and managers along the whole Line and Staff Organization. In fact, the results of an extensive investigation carried out as expert appointed by the public prosecutor, based on in depth analyses of fatal accidents occurred in industries and construction yards: the sub-causes of the first one, are poor Hazard Identification (HI), uncritical Risk Assessment (RA) and, consequently, Risk Management (RM) lacking of a Quality approach.

Figure 5 summarizes: the sequence covers poor HI -the Hazard Factor was not recognized, or identified with a too generic description (90% of the cases)- uncritical Risk Assessment and, consequently, Risk Management inadequate and lacking of a Quality approach. (*De Cillis et al., 2017a*) all the mentioned causes are attributable to an insufficient "Culture of Safety", this being a general problem, with particularly serious consequences when critical NACE sectors are involved.

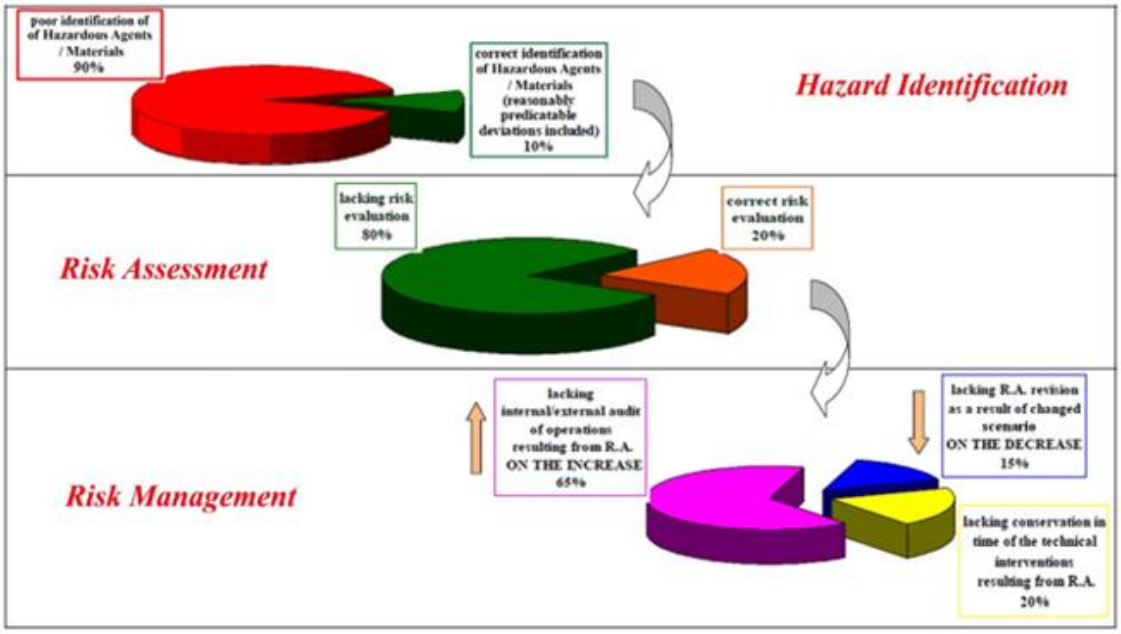


Figure 5 -Causes of fatalities in industries and construction sites – source De Cillis 2017

In fact, analyzing a number of occurred work related accidents by means of the special technique described in the previous chapter (Computer-aided Cause Consequence for Prevention – CCCP (*Luzzi et al., 2015*)), in many even recent cases the result shows a remarkable disconnection between:

1. the Design, and a throughout Risk Assessment,
2. the Safety Management conceived at the Design phase, and the implementing phase.

To discuss the consequences of these disconnections, the following diagram (from Motivation of the issuing of the Directive 92/57/EEC, EU Law and Publications Office, Luxembourg, 1993), highlights the costs-errors relationship in the different phases of a project (Figure 6).

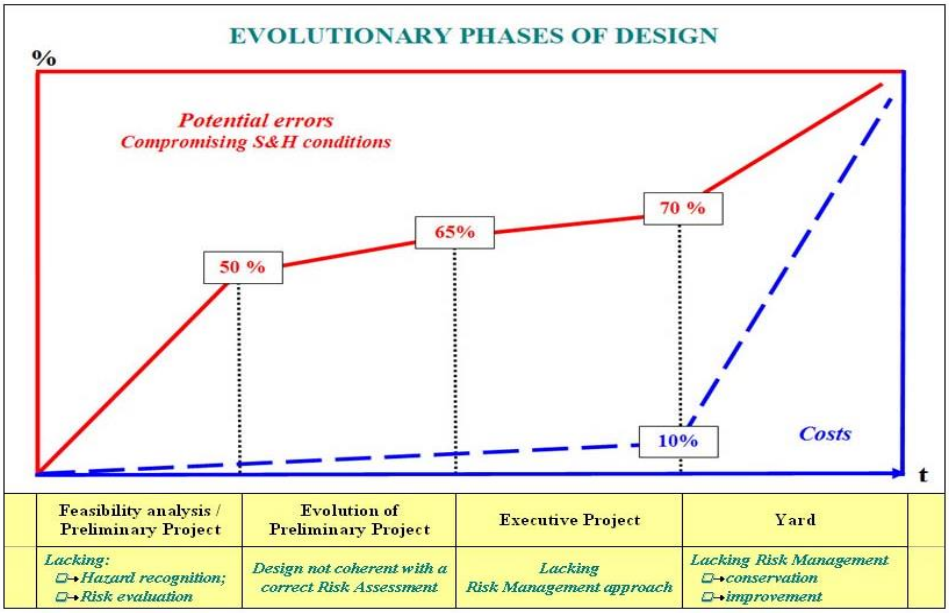


Figure 6 - Time evolution of costs / errors. The Authors demonstrated analogous trends in a number of industrial NACE sectors, with some minor shift of the costs line.

The evolution of the approach to the OS&H problems, in accordance with the statements of the EC Directives laying at the very base of the National law and regulations on the Health and Safety of workers at work, involves the need of widespread dissemination of a Culture of Safety. Such a culture should be based on the principles of motivational training and, as seen, include all the people involved at the different levels of responsibility.

1.5 Research Questions

A. *Can we consider the Culture of Safety a necessary tool to improve the system?*

B. *If Safety is a Science, how should it be effectively disseminated?*

C. *Does a general effective approach exist, or it is necessary to develop a peculiar one in every situation?*

D. *Is the Culture of Safety measurable? How can we quantify it?*

E. *Does the Culture of Safety need to keep up with the times?*

1.6 Research Approach

To achieve the research aim, first the results gained in Occupational Safety and Health field in literature and in practice have been analyzed: the identification of criticalities linked to the dissemination of the knowledge was the starting point to classify the existing approaches and to design new ones easy to be addressed to the entire population.

This research thereby follows the basic idea of design science, which does not just evaluate existing practices, but also contributes by developing new ideas and approaches. In fact, based on the identified criticalities, tools have been developed to overwhelm these difficulties.

For the *problem exploration*, a multiple-case study within various asset are used to confront and reflect on the theories gained so far.

The Case Studies analyses can be divided in 2 steps: an exploratory phase to study and understand the problem in practice, followed by a design and evaluation phase to develop peculiar solutions addressed to the problem.

This study hereby aims to offer theoretical insights by identifying to what extent these assumptions in the literature correspond to the current practice. The results of this multiple-case study reveal main system's difficulties that OS&H practitioners experience in peculiar situations even in the application of the Regulation.

Some solution to these difficulties structure have been reached:

1. analyzing the existing solutions and considering:

- a rigorous definition of the operative scenarios, and a coherent selection of techniques and technologies suitable to face possible incidental chains. This requires a project conceived by designers with adequate Culture of Safety, and the subsequent implementation (e.g., in the case of constructions, the result depends on the Culture of people responsible of the Safety and Coordination Plans);
- the inclusion in such scenarios, and at the different levels, of operators aware of their responsibilities vs Safety, and able to distinguish whether the situation conforms with the design conditions, or presents deviations

(faults, disconformities, etc.): these should be immediately identified, to introduce the necessary remedial measures.

2. Selecting the most suitable technique if any – or mixing the existing to obtain a peculiar one; on this basis, the target of an effective prevention can be reached, also in complex situations, within a system strictly correlated with the technical measures for minimizing the risks which cannot be eliminated (i.e. based on approaches in Prevention through Design – PtD and Quality Management of the activities).

3. Identifying the OS&H lacks, the workers involved and most suitable candidates to be trained; to point out the best dissemination techniques, decision makers should ensure a multidisciplinary approach in each situation, never forgetting all the links of an Educational process, from the identification of the audience' cultural background, to the auditors' expectancies and the predefined formation goals. This screening on the different approaches found in literature, integrated with our direct experiences, is aimed to provide a first step of structured approach to the complex issue of an effective Identification of suitable Educational processes. Creating a methodical collection of Educational campaigns can help people involved in the Information Formation and Training sector, to compare, assess and improve the quality of their activities to define the most suitable in every situation.

4. Assessing the added value of interventions: however, the designed approaches are not the sole outcome: the design and its assessment also lead to a deepen understanding of the mechanisms that deliver the outcome to a dynamic solution adaptable to evolving needs. every intervention should be assessed in order to measure the impact it had in the context where it was implemented. To understand the challenging task to quantify the level of Safety, it is necessary to jump in the past, when Safety was considered as *the non-occurrence of an unwanted event (Safety I)*, and then changed to *Safety II* as *the ability to succeed under expected and unexpected conditions alike*. In Both cases it was hard to identify indicators to predict the Safety level. Talking about Culture of Safety, this goal becomes even more complicated, in the cases analyzed it was required to assess and quantify the

advantages obtained after the interventions, keeping in mind that those kind of changes can take years to root in the company believes.

The effective quality and sustainability of a system requires the fulfillment of the OS&H principles, which in turn requires a correct Risk Assessment and Management (RAM).

The final goal is to have an integrated system, resulting in a positive change of the situation, of the behaviors and of the way to face the OS&H matters, not only a huge quantity of paper that demonstrate that some Information Formation Training was organized.

To make people change, and consequently to improve the System, it is necessary to make workers aware and keen to participate in this change (the Education Learning Change process).

Educational processes result precious for a correct dissemination of the "Culture of Safety". As seen, the goal is to transmit information to all the workers, regardless to their previous knowledge and background. a large number of Educational approaches have been analyzed, stressing strengths and weaknesses, not in absolute terms, but taking into account the related typology of audience.

It is possible to summarize such spirit in the pivotal concepts of Prevention intrinsically linked to the design and manage the dissemination of Culture of Safety in Quality approach.

In the thesis some examples are described of construction activities in which was developed a specific Cultural design (implying full synergy of management and employees as actors with different tasks and skills).

Within a project carried out by the Biomechanics & Ergonomics Lab, at Northeastern University, (Department of Physical Therapy, Movement, and Rehabilitation Sciences, Bouvé College of Health Sciences) in cooperation with other Universities and Public bodies of Massachusetts, was developed and tested a tool to measure the Safety climate of contractors and sub-contractors, taking into account all the efforts and the intervention in OS&H implemented by the managers.

A chapter is dedicated to the link between Safety and Innovation, in particular it is necessary to keep pace with Industry 4.0 and all the new technologies available, to better understand the needs of the employers and of the workforce, both always evolving.

1.6 Outline

Table 2 describes the structure of the thesis, stressing the importance of the dissemination of the Culture of Safety for every intervention analyzed or implemented.

Table 2 - structure of the thesis

		PHASES		
#	**DESCRIPTION**	**PROBLEM EXPLORATION**	**SOLUTION**	
			DEVELOPMENT	**DISSEMINATION**
1	OS&H context	investigation about the causes in an evolving context	Software - CCCP	Prosecutor investigations International Meetings, papers, conferences thesis
2	The Culture of Safety as key to improve the system	Analysis of International and multidisciplinary literature to know the State of art		
3	OS&H Education process in	identification of different targets and interventions	Students Workers	classes lectures, training, internship
4	Implementation of dissemination of the Culture of Safety principles in NACE sectors	linear yards	technical organizational	software, papers, conferences,
		great works	design phases techniques organization innovations	International Meetings, papers, conferences
		stage collapses	Clarify the Regulations	thesis
5	Development of a pre-qualification tool in Construction sites.	absence of objective methods to evaluate the Safety Climate of Sub-Contractors in construction sites	development of surveys and worksite recruitment; results have been analyzed through an R code	involvement and sensitization of recruited companies (*future publication intention*)
6.	Safety and Innovation	Safety in the evolving working context	technologies research regulations workforce	International Meetings, Conferences, special number of a journal.
7	***Discussion and Conclusion***			

1.7 List of Publication

1. E. De Cillis, D. Labagnara, L. Maida, C. Masucci (2014): "Valutazione e gestione dei rischi per la salute dei lavoratori nello scavo meccanico di gallerie". GEAM, geoingegneria ambientale e mineraria, vol. 143 n. 3, pp. 93-103, ISSN 1121-9041
2. L. Sambuelli, P. Fargione, E. De Cillis, M. Patrucco: "Geophysics and Tunneling - the how and the why: a focus on the why", 21st European Meeting of Environmental and Engineering Geophysics Near Surface Geoscience 2015, 6 - 10 September 2015, Turin, Italy
3. C. Cirio, E. De Cillis, L. Maida, M. Patrucco: "Mobile Elevating Work Platforms: a discussion on the main causes of accidents and some suggestions for prevention", Proceedings of the 25th European Safety and reliability conference - ESREL 2015, 7-10 September, Zurigo, pp.3229-3236, CH Safety and Reliability of Complex Engineered Systems – Podofillini et al. (Eds), © 2015 Taylor & Francis Group, London, ISBN 978-1-138-02879-1
4. E. De Cillis, L. Maida, M. Patrucco: "Computer-aided Advanced Technique for the Analysis of Occupational Accidents", 8th edition of International Conference WOS.net Smart Prevention for Sustainable Safety – Porto 2015, 23-25 September
5. C. Cirio, P. Fargione, L. Maida, C. Meloni, M. Patrucco, E. DeCillis, R. Borchiellini: "Occupational Risk Assessment and Management at the highway maintenance yards: suggestions drawn from some experience in Italy" presentation to the 8th edition of International Conference WOS.net Smart Prevention for Sustainable Safety – Porto 2015, 23-25 September
6. E. De Cillis, M. Patrucco, R. Borchiellini, P. Fargione: "Risk Assessment and Management: easier said, perhaps with too many words, than done - the importance of the culture of prevention", in SHO 2016 - The Occupational Safety and Hygiene Symposium, Guimarães, 23-24 marzo 2016, Guimarães (Portugal), ISBN: 978-989-98203-6-4
7. C. Cirio, L. Maida, M. Patrucco, E. De Cillis: "Innovative technologies and related accident scenarios: the importance of the Culture of Safety in activities involving Mobile elevating Work platforms" GEAM, geoingegneria ambientale e mineraria, Anno LIII, vol. 16, n. 1, Aprile 2016, pp. 21-30, ISSN 1121-9041
8. E. De Cillis, P. Fargione, M. Patrucco: "Tips on Occupational Safety and Health – OS&H", GEAM Geoingegneria Ambientale e Mineraria Anno LIII, vol. 16, n. 3, DICEMBRE 2016, pp. 65-68, ISSN 1121-9041
9. E. De Cillis, P. Fargione, L. Maida: "Some results of a modern approach to the Occupational Safety and Health problems", Proceedings 9th International Conference on the Prevention of Accidents at Work (Wos 2017), 3- 6 October 2017, Prague, ISBN 978-1-138-03796-0
10. E. De Cillis, P. Fargione, L. Maida, M. Patrucco: "An experience of University Education on Occupational Safety and Health at Politecnico di Torino", Proceedings 9th International Conference on the Prevention of Accidents at Work (Wos 2017), 3- 6 October 2017, Prague, ISBN 978-1-138-03796-0
11. E. De Cillis, P. Fargione, L. Maida: "The dissemination of the Culture of Safety as an essential tool for the improvement of working conditions and production efficiency: discussion on the multidisciplinary approach and main sub-topics", GEAM Geoingegneria Ambientale e Mineraria Anno LIV, n. 2, Agosto 2017, pp. 109-117, ISSN 1121-9041
12. E. De Cillis, P. Fargione, L. Maida: "The dissemination of the Culture of Safety: innovative experiences from important infrastructures and construction sites", GEAM Geoingegneria Ambientale e Mineraria Anno LIV, n. 2, Maggio – Agosto 2017, pp. 118-127, ISSN 1121-9041
13. E. De Cillis, M. Patrucco, R. Borchiellini, P. Fargione: "Risk Assessment and Management: easier said, perhaps with too many words, than done - the importance of the

culture of prevention", in SHO 2016 - The Occupational Safety and Hygiene Symposium, Guimarães, 23-24 marzo 2016, Guimarães (Portugal), ISBN: 978-989-98203-6-4

14. R. Borchiellini, C. Cirio, E. De Cillis, P. Fargione, L. Maida, M. Patrucco: "Occupational Safety and Health in Highway Maintenance Yards: an Approach Suitable to Face Special Criticalities", Chemical Engineering Transactions Vol. 57, 2017, pp. 313-318, DOI: 10.3303/CET1757053, ISSN 2283-9216
15. R. Borchiellini, C. Cirio, E. De Cillis, P. Fargione, L. Maida, M. Patrucco: "Criticalities on Highway Maintenance Yards: Some Suggestions to Improve the Effectiveness of OS&H Supervision/Inspection Activities", Chemical Engineering Transactions Vol. 57, 2017, pp. 397-402, DOI: 10.3303/CET1757067, ISSN 2283-9216
16. E. De Cillis, P. Fargione, L. Maida, M. Patrucco: "An experience of University Education on Occupational Safety and Health at Politecnico di Torino", Proceedings 9th International Conference on the Prevention of Accidents at Work (Wos 2017), 3- 6 October 2017, Prague, ISBN 978-1-138-03796-0
17. De Cillis E., Demichela M., Fargione P., Maida L., Nebbia R., Patrucco M.: "Education: an essential tool for the dissemination of the culture of Safety". Chemical Engineering Transactions, Vol. 67, 313-318 DOI: 10.3303/CET1867053, 2018, ISSN 2283-9216
18. De Cillis E., Fargione P., Maida L., Patrucco M., Sambuelli L.: "Present and future contribution of Geophysics to the Prevention through Design and Quality Management approaches for tunneling operations". First Break, Vol. 36, pp 35-41, October 2018, DOI: 10.3997/1365-2397.2018005
19. C. Ciocan, E. De Cillis, F. Donato, G. Garzaro, M. Patrucco, E. Pira: 'Evoluzione del concetto di OS&H dal secondo dopoguerra ad oggi: dal sistema prescrittivo alla Valutazione e Gestione dei rischi in qualità di sistema – il modello esteso in collaborazione alle grandi strutture. Evoluzione della cultura multidisciplinare della sicurezza e OS&H', GEAM Geoingegneria Ambientale e Mineraria Anno LV, n. 2, Maggio-Agosto 2018, pp. 16-20, ISSN 1121-9041

Chapter 2

The Culture of Safety

Can we consider the Culture of Safety a necessary tool to improve the system?

2.1 State of the art

Considering the Occupational Safety and Health conditions along 1.5 centuries, e.g. from the beginning of the modern industrialization, an impressive progress appears evident, thanks to the improvements of mechanization, social conditions, techniques and technologies, results of epidemiological research work, and the introduction of quality systems and European approaches to the OS&H.

Only the full consciousness of the need of a widespread Culture of Safety may in the future contribute to the completion of the positive trend of Figure 7 (*Patrucco and Sorlini, 2017*), in which the various contributions of technical and social progress have already led to a substantial improvement in the Safety performance index, generically intended as an indicator of the Safety condition in the productive performance.

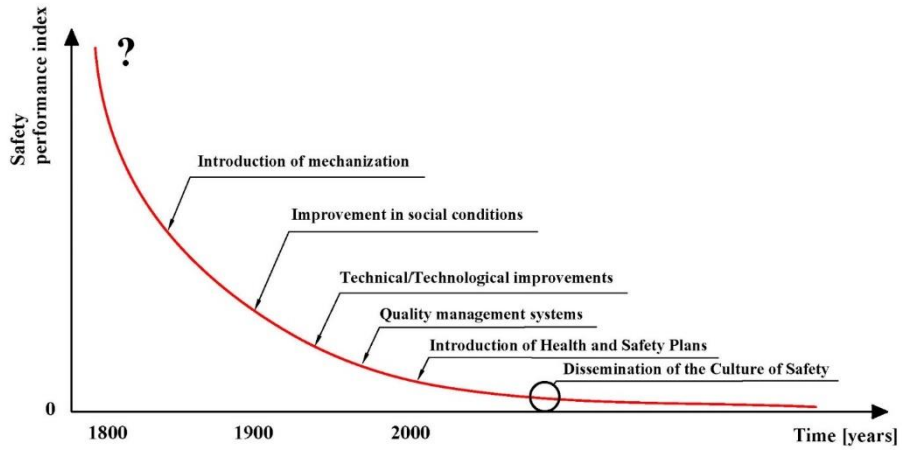


Figure 7 - the decreasing trend of the Safety performance index: currently, the results are very close or, in some recent cases, achieved the goal of ZERO fatalities, and a low number of severe injuries.

However, European and national statistics on accidents and occupational Health impairments show today a still unacceptable situation.

The Culture of Safety should be considered an essential tool for the effective prevention in ethically and economically sustainable production systems, able to oust the widespread incapability to act according to the OS&H spirit, and the passive approach of people involved –typically practitioners in the construction sites field- seldom contributing actively since still firmly convinced that OS&H is a part of a compartmentalized system (Safety-production).

2.2 The Culture of Safety and its dissemination

The Culture of Safety, is *the enduring value and prioritization of worker and public Safety by each member of each group and in every level of an organization* (*Von Thaden, Gibbons, 2008*)

First, it is important not to mix the two distinct concepts of a) Culture of Safety and b) Information Formation and Training - IFT. Where the Culture of Safety is missing, the IFT, mandatory by law, results in a hodgepodge of procedures written in an evident personal approach (*Reason, 2000*) without any reference to a serious Risk Analysis (the already mentioned *paper-based Safety* appears again).

The international literature on the Culture of Safety - as result of a multidisciplinary approach - is very wide broad. This is the result of a challenging critical effort to classify and organize the different covered sub-topics into homogeneous sub-categories, precious as a key reading and reference for framing and analyzing, in an unbiased approach, the OS&H system faults in real cases.

To this purpose, as in the current historical and philosophical debate of other scientific disciplines, an investigation about Safety Ontology, that is on the true basis of Safety, became necessary.

2.2.1. *The value of the Culture of Safety dissemination (in compliance with the Safety and Health Regulations and Standards*)

"Before to start the process of Culture of Safety dissemination, it was necessary to define what Safety was. It became of pivotal importance to confine the meaning of Safety and define a common agreement on what we should have focused on" (*Hollnagel, 2014*). One of the pivotal changes in Safety conception was the change from Safety I, intended as the non-occurrence of an unwanted event, so a "non-event", to Safety II, defined as the ability to succeed under expected and unexpected

conditions alike, so that the number of wanted outcomes is as high as possible (*Eurocontrol, 2013*). Finally, considering Safety as a factor of a well working system, it could be object of systematic research in order to augment the information level on the latest trends in this field and, being multidisciplinary, to spread the knowledge to all practitioners involved in system the management.

Safety became a real Science (*Dennett, 1995*), so it had to fit with the "four sets of institutional imperatives taken to comprise the ethos of modern science: universalism, communism, disinterestedness, and organized skepticism" introduced by the American sociologist Robert K. Merton in 1973.

Nowadays, we can state that Safety is a system of organized and systematic knowledge production, considering the scientific system as the unity of actors (research groups and scientific communities, and all institutions) that conduct the researches, and, through the complex structures (journals, papers, books,..), spread the knowledge at different levels to create a real educational system (*Aven, 2014*).

A resume of the scientific production in the last 50 years since the first journal about Safety topics.

Journal	Year of first publication	Area of main focus
Accident analysis & prevention	1969	Road Safety
Journal of Safety Research	1969	Occupational Safety North America
Journal of Hazardous Materials	1975	Technology of Safety
Safety Science, previously Journal of Occupational Accidents	1976	Occupational Safety, Safety management and culture
Journal of Loss Prevention in the Process Industries	1988	Major hazard technology & management International
Journal of Occupational Safety and Ergonomics	1995	Ergonomics and occupational Safety
Policy and Practice in Health and Safety, previously Journal of the institution of Occupational Safety and Health	1997	Policy and regulation
Reliability, Engineering and System Safety	1998[a]	Major hazards and quantitative risk assessment
Journal of Risk research	1998	Risk perception and governance

Figure 8 - list of journals about Safety in the last 50 years

Following this line of thought and gaining a clear overview of the situation, it is clear why the dissemination should be wide.

It was obsolete to think that accidents occur inevitably in many hazardous technical systems *(Perrow, 1999),* whereas we started talking about "chain of causes" as in the Heinrich's domino model *(Heinrich, 1931)* or Swiss cheese model (*Reason, 1997*) about the line-up of barriers' failures.

In this light, every barrier failure is a cause, but the Identification of Causes is not sufficient to make an effective Prevention.

2.2.2. *Starting point: work related accidents and Health impairments*

As described in the previous chapter, the data available is a good starting point to understand the criticalities and program the intervention. The main causes of the work-related accidents and Health impairments situation are:

- ✓ the technological context, notwithstanding the important progress also in terms of Safety and Health,
- ✓ the evolutionary socio-economic scenario,
- ✓ the more and more diversified composition and origin countries of the workforce,
- ✓ difficulties in the implementing of preventive measures in complex and constantly evolving production situations.

Starting from the analysis of national and international databases, training designers should analyze occurred work-related accidents in the NACE sector where they are going to intervene in order to find out the main Risks connected to the activities and, consequently, design a training as effective as possible *(Cirio et al., 2015*).

2.2.3. *The need of a specific competence in techniques, technologies and OS&H*;

It is of pivotal importance a thorough analysis, using suitable tools to better understand the why of the deviations occurrence, and why practitioners involved noticed –or did not notice- the anomaly and did not break the chain. By means of special techniques (i.e. Computer-aided Cause Consequence for Prevention – CCCP), they could easily understand the Chain of Intermediate Events up to the Root Causes, and find the breaking point. (*Borchiellini et al., 2017a*).

In some accidents analyzed within prosecutors' mandate, we confirmed that one recurrent cause is the lack of a general Culture of Safety (*Cirio et al., 2016*) of all people involved at the different levels.

A study developed at Politecnico di Torino, underlines how in many cases the analysis points out remarkable disconnections between:

a. the general Design, and a throughout Risk Assessment,

b. the Safety Management conceived at the Design phase, and the implementing phase *(Borchiellini, et al., 2016).*

2.2.4. *Culture of Safety at all levels*

It is necessary to collect data and information from all the levels of the system: a spread awareness is important because individuals' erroneous assumptions let events go unnoticed or misunderstood, and often rigidities of human belief and perception can lead to a disregard of complaints and warning signals from outsiders. This leads to judgment errors, cognitive lapses, deficient supervision and communication difficulties that Safety scientific orthodoxy sees as critical in creating a discrepancy between a safe system and an actual system state *(Reason, 1997).* It is important to highlights that a failure is the result of an event chain that someone, somewhere, did not anticipate or did not stop on time *(Weick and Sutcliffe, 2007).*

So, managers' education needs an empowerment in decision making under conditions of uncertainty and historical understanding (as individual and organizational memory), and in communication capabilities also towards low-level workers. Moreover, the empowerment of lower-ranking individuals and reminding them of their responsibilities is important: the prevent-harm ethics, i.e. awareness and knowledge on the OS&H themes, becomes the fundamental approach *(Feldman, 2004).*

Moreover, to improve the OS&H awareness, every link of the chain should be considered: to ensure Safety in the whole system, from the first to the last stage of the work, none worker of the site should be neglected in the top-down assessment.

Decision makers in particular need to find common language and concepts to legitimately have a comparison with low-level workers to reach a better balance between conceptual and operational knowledge.

2.2.5. *Goals to reach in terms of basic knowledge / competences of workers and other actors*

It is necessary to clarify the basics of workers Safety Culture's gaps, and the necessary educational interventions.

In particular, the combination of technological and economic changes and Europe's demographic challenges (i.e. the immigration and the ageing of the working population), makes that necessary in the Member States.

According to the Brussels European Council of March 2006, lifelong learning is essential to achieve the Lisbon objectives in terms of:

- ✓ Knowledge as the "understanding of or information about a subject that you get by experience or study, either known by one person or by people generally" or "the state of knowing about or being familiar with something" (*Cambridge dictionary*). It can be referred to a field of study or a job in the context of European Qualifications Framework (EQF); knowledge is described as theoretical and/or factual.
- ✓ Skill is the ability, practice, aptitude, etc., to do something well and, in the context of EQF, skills are described as cognitive (involving the use of logical, intuitive and creative thinking), and practical (involving manual dexterity and the use of methods, materials, tools and instruments).
- ✓ Competence as a cluster of related abilities, commitments, knowledge, and skills that enable a person (or an organization) to act effectively in a job or situation.

In the context of EQF, competence is described in terms of responsibility and autonomy.

Applying these concepts to Safety & Health problems at workplaces, would be necessary to identify, analyze the deviations and every gaps in the system, and intervene to obtain safer and Healthier workplaces, trying to involve all the co-workers.

According to the previous chapter (Culture of Safety at all levels) each level of responsibility has its own requirements: so, from the Prevention through Design - PtD phase to the execution time, actors involved must have Competences in the sense of combination of knowledge and skills that enable them to act in a wide variety of situations.

2.2.6. *Find target*

Educational system should stem from the important concept of having precise and obtainable objectives of each activity, measurable and defined at the outset (*Tyler, 1949*).

It is necessary to bear in mind that the vast majority of students who will attend Safety & Health training sessions are adults who already possess knowledge, skills, and abilities to work in their current occupations or sincerely believe they have. If some behavior is not coherent with correct Safety the problem becomes challenging. Workers have a wide experiential base, over time, they have accumulated many concepts, a practical approach to learn and operate (*Brookfield et al., 1995*) so that they directly connect the "Basics" learned examining Reality, and often they are not willing to accept uncritically what has been said.

From this perspective, it becomes of pivotal importance to understand what should be the correct approach with this kind of learners. The first who thought that adult education processes should be distinguished from the more common pedagogy (Greek: "*child-leading*"), was the American educator Malcolm Knowles (1913-97), who popularized the term Andragogy (Greek: "*man-leading*") coined by German educator Alexander Kapp in 1833. This term refers to the method and practice of teaching adult learners, the adult education: through it, Knowles explained his collection of ideas about adult learning processes, and he turned it in a real Science to "understand" (theory) and support (practice) lifelong education of adults (*Knowles, 1973*).

It is important to know that, due to the fast evolution of work situations, some purposes can emerge subsequently to the design and schedule, the intervention should then be developed and delivered continuously taking into account that Safety Competences can occur in any period of people's life or at any stage of their career.

As OSHA states "Quality in Occupational Safety and Health training provides the tools to protect workers' Health and lives and to prevent work-related injury or Health impairments. Effective training develops workers who are educated and empowered to improve the working conditions in their workplaces", giving them an active role.

2.2.7. *Subjects / organizations involved*

The dissemination of Culture of Safety requires a comprehensive methodological approach to make workers be part of the organizational system, to support processes in place and to deal with changes and potential arising problems. It is important to draw an exact organization chart to identify people involved and

their position in the organization, in the decision making process and, above all, their duties and responsibilities in OS&H matters.

Before to start the educational process, it is necessary to make them aware about their role because adults need to know the reason for learning something and are most interested in learning subjects having immediate relevance to their work and/or personal lives. The need is to implement their skills continuously, at all levels, in the economic interests of both the company and the worker and, last but not least, the social need to respond positively to the risk of exclusion, deprivation and marginalization (*Knowles, et al., 1984*).

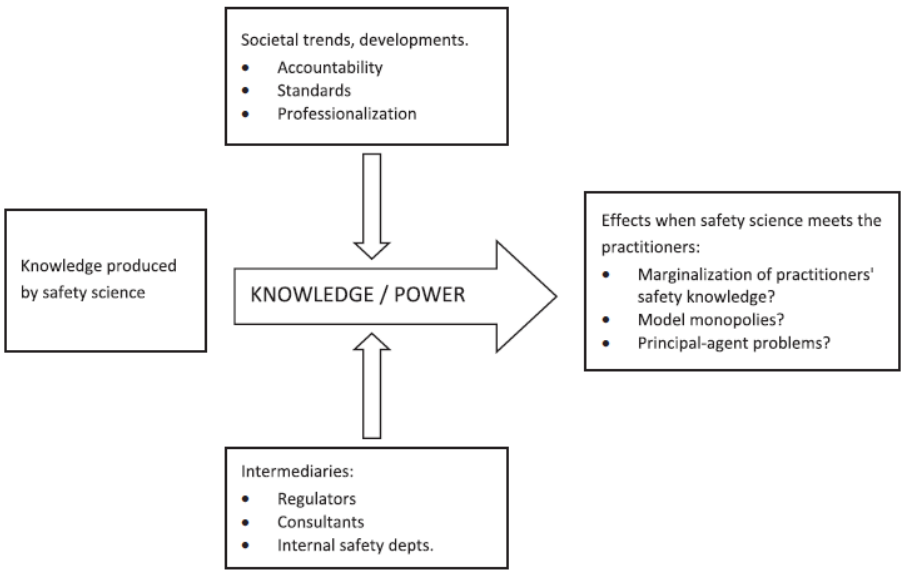


Figure 9 - analytic model – source *Almklov*.

Of course, Employer has to comply the Regulations that cover specific topics and their scheduling in terms of both time and discussion of theoretical aspects and practical developments, to be in line with the official requirements. The Italian Law 81/08 and s.m.s. -enforcement of the 92/57 EEC Directive- Annex XIV- requires the minimum content of 120h training course for Coordinator for Safety and Health at the project preparation stage, and Coordinator at the project execution stage.

Employers should identify the global and specific needs of people involved in the organization - the learners - and their background, the structured courses and the Training intervention on specific Safety issues (deriving from a thorough Risk Assessment).

The final goal is to have an integrated system, resulting in a positive change of the situation, of the behaviors and of the way to face the OS&H matters, not only a huge quantity of paper that demonstrate that some IFT was organized.

To make people change, and consequently to improve the System, it is necessary to make workers aware and keen to participate in this change (the Education → Learning → Change process).

2.2.8. *Overview of best practices: Context and learning needs assessment, Specific stakeholders*

‘‘Information flow’’ means a transmission of details, but more information is not necessarily better.

Good information should have these characteristics:

a) it provides answers to the questions that the receiver needs answered;
b) it is timely;
c) it is presented in such a way that it can be effectively used by the receiver (*Westrum, 2014*).

The information flow is deeply linked to the culture of Safety of the organization (*Curry et al., 2011*).

As already stated, adults are voluntary learners; they should understand the reason and decide they need to learn something: they learn needed information quickly if they realize that matter and methods are relevant to make their lives easier. Moreover, if they are experienced, it should be good to encourage them to share their experiences and knowledge. Adults learn more when they participate in the learning process and when they know where they are heading: adults need to be involved and actively participate in the class. Field training is a good opportunity because they learn better by doing, they need to "try-on" and practice what they are learning.

2.2.9. *Dissemination of the Culture of Safety in a quality approach*

The education and the training processes require a comprehensive methodological approach to be an integrated part of the organizational system, and to support the processes: of course, to deal with changes and processes’ evolution - and the related problems, it should be repeated.

Having a written quality assessment and control plan will help to ensure overall the high-level of a training program. Quality control plan is not the same as training evaluation: it can ensure that each element of the system has been done well and is achieving its goals, and provides a tool to review periodically the program and improve it if needed.

Similarly, to the Safety Documents, the training program also needs to evolve following different phases. Project Designers should periodically review the written Quality assessment & control plan and update it as appropriate. This provides an opportunity to be sure that the program:

- ✓ includes all applicable regulatory changes;
- ✓ implements course updates that have occurred during the preceding period;
- ✓ integrates new training technologies;
- ✓ integrates new modules within the training program.

The current training system is experiencing a strong evolution: linked to changes in the social context and the educational objectives, it is changing its own processes. This is a challenge for the educational process that must quickly adapt to these changes: a quick and effective change can only occur if there is a continuous process of monitoring aimed at identifying influential factors on the system and its shortcomings.

The dissemination of the Culture of Safety is an essential step towards an increasingly effective preventive action.

In line with the general engineering approach - confirmed by the transposition of the OS&H European Directives - the setting and management of the Safety and Health at Work, together with the Protection of third parties and Environment, have been since many years based on both PtD and Management in a Quality approach.

On the other hand, the most obvious milestones of Safety – Quality are:

- ⇨ Safety, like quality, becomes clearly visible when it fails;
- ⇨ Safety, such as quality, must be understood and shared by all involved;
- ⇨ Safety, like quality, must be managed with preventive and non-corrective actions;
- ⇨ Safety, such as quality, must first be culturally understood and implemented by those with high decision-making power.

With special reference to the last point, organizations should not read it in the sense of identifying decision makers who, according to an approach dating back to

the last century, are exclusive providers of Safety towards subjects whose only obligation is to comply with prescriptions. Often it results too generic and unclear, whilst it should be understood constructively as part of a widespread dissemination of the Culture of Safety

Universities also can play their part: there are examples of synergic and multidisciplinary collaboration that made it possible to achieve appreciable results (*Borchiellini et al., 2015*).

2.2.10. *Not only Information, Formation and Training, but Promotion*

Some practitioners considers the training process as a "philosophy" whose core idea is that the Health and Well-being are an achievement / individual and collective responsibility *(Taylor, 1995)* whereas others *(Ewles and Simnet, 1999)* consider the planning phase as a set of activities:

- ⇨ - Education / Communication: addressed to those who hold power in the organization;
- ⇨ - Prevention of Occupational disease and impairments to reduce the social impact;
- ⇨ - Health protection: legal, fiscal measures, policies, ..

Promotion of Safety and Health has a wider range than Prevention (whose purpose is limited to the maintenance of the Health status) and requires that:

a) workers check their Safety and Health and the influencing factors that influence it;

b) the whole community is involved (as individuals and groups) in promoting initiatives concerning Safety and Health for the benefit of all the organization members, but also of a wider circle of stakeholders.

2.3 In closing

On the basis of an in-depth analysis of the data, it has been confirmed that one essential step to correct the scenario consists in a substantial enhancement of the dissemination of the Culture of Safety.

Figure 10 - Culture of Safety as a result of several sub-topics

Since the Culture of Safety is clearly based on a broadly multidisciplinary approach, covered by very wide international literature, it was necessary to classify and organize the different covered sub-topics, precious as a key reading and reference for framing and analyzing in an unbiased approach the OS&H system faults in real cases.

Chapter 3

OS&H Education

If Safety is a Science, how should it be effectively disseminated?

3.1 Safety as a Science

Finally, considering Safety as a factor of a well working system, it can be object of systematic research in order to augment the information level on the latest trends in this field and, being multidisciplinary, to spread the knowledge to all practitioners involved in the management (Editorial, *Safety Science, 2014*).

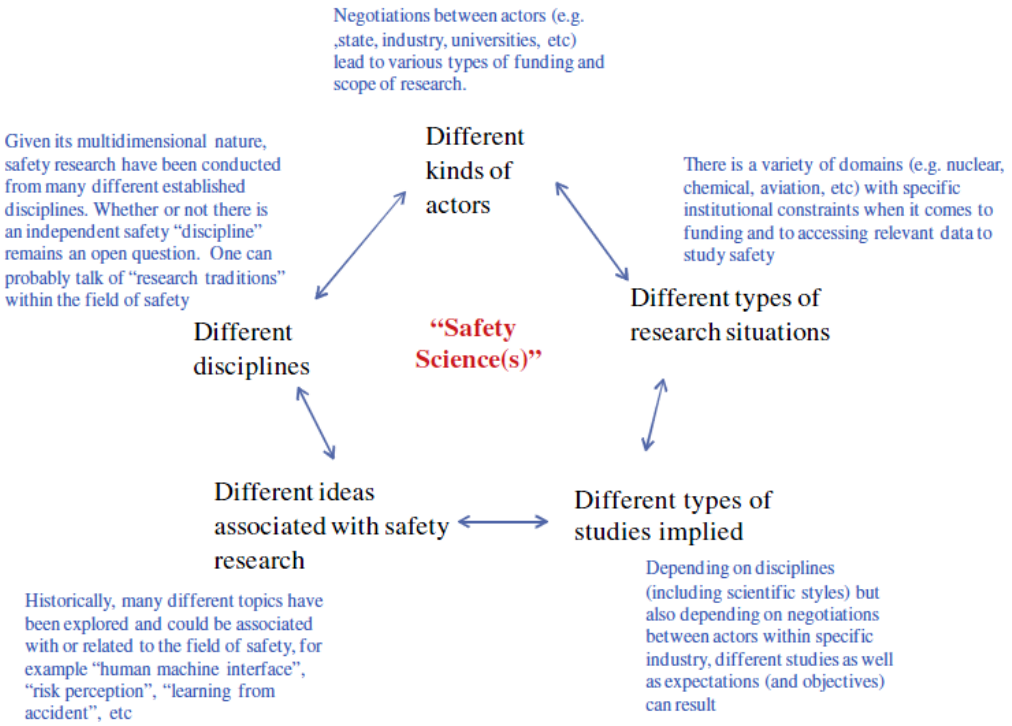


Figure 11 - Safety studied from many different perspectives – Source: The foundations of Safety Science

Safety becomes a real Science, so it has to fit with the "four sets of institutional imperatives taken to comprise the ethos of modern science: universalism, communism, disinterestedness, and organized skepticism" introduced by the American sociologist Robert K Merton (*Merton, 1973*).

Therefore, it is a system of organized and systematic knowledge production, whereas the scientific systems is the unity of actors and structures, in which the actors (research groups and scientific communities, and all institutions) conduct the

researches and, through the complex structures (journals, papers, books,..), spread the knowledge at different levels and creating a real educational system (*Aven, 2014*).

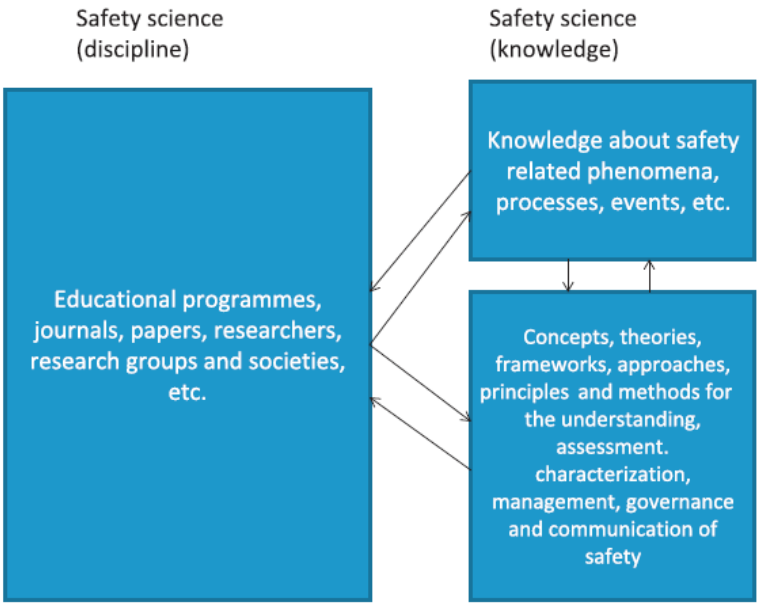


Figure 12 - An illustration of the difference between Safety science as a discipline and the knowledge part of Safety science – source Aven 2014

In this scenario, different actors, disciplines, ideas, research themes and approaches need to be coordinated, the fragmentation - derived by the multidisciplinary approach - makes essential to identify and examine in depth the common basis of the Safety Science in different disciplines.

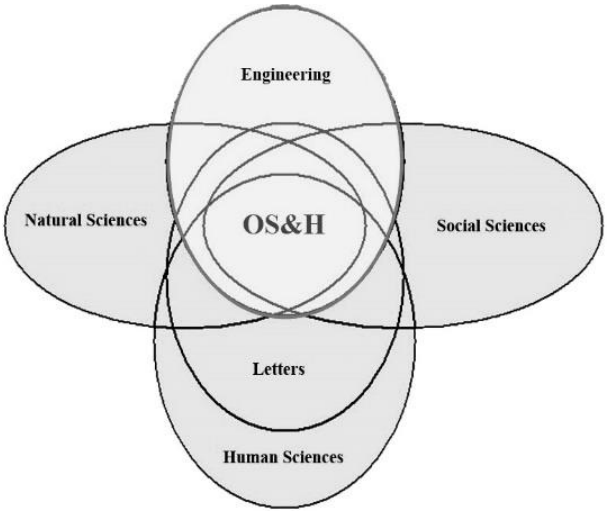


Figure 13 - Multidisciplinary of OS&H, Modified From A Ceca - European Coal And Steel Community - Document Of Late '50

Following this line of thought, it is clear why the dissemination should be wide.

Talking about Culture of Safety is important not to mix the two distinct concepts of IFT, and the Educational Process.

In general terms, since Safety and Health concern everybody, the Culture of Safety should be disseminated to the entire population. To avoid confusion, it became necessary to divide the wide field of Education in main macro groups concerning workers' Information Formation and Training, School path and the Lifelong Learning process.

3.2 Workers Education

3.2.1 Workers as Adults

It is necessary not to forget that, the vast majority of students who will attend Safety & Health training sessions are adults who already possess the knowledge, skills, and abilities to work in their current occupations.

From this perspective, it becomes of pivotal importance to understand what should be the approach with this kind of learners. The first who thought that adult education processes should be distinguished from the more common pedagogy - Greek: "child-leading", was the American educator Malcolm Knowles (1913-97), who popularized the term Andragogy - Greek: "man-leading" (coined by German educator Alexander Kapp in 1833).

This term refers to the method and practice of teaching adult learners, the adult education: through it, Knowles explained his collection of ideas about adult learning processes, and he turned it in a real *Science* to "understand (theory) and support (practice) lifelong education of adults. *(Knowles, 1973).*

The need of adults' education developed after the II world war, rose in a climate of social and economic growth, during a period of progress and innovation too fast to be supported by contemporary spread knowledge. In that scenario, in particular in workplaces, came out the need to re-train workers to make them part of the new system, considering them as a real capital.

"During the period of prosperity, monetary capital grows at relatively higher rate while during the period of recession and depression there is deceleration of monetary capital. On the other hand, human capital has uniformly rising rate of growth over a long period of time because the foundation of this human capital is laid down by the educational and Health inputs" (*Becker, 1964*).

Human beings started to be considered a *Resource* and rose the role of Human Resource Developer (HRD), designed to maximize employees' performance in service of employer's strategic objectives. In this background, Malcolm Knowles conducted sessions at many large national conferences to help HRD understand learning theories as applied to adults. In 1973, he finally wrote down his thoughts and brought together his various sources so the result was a book to share by a wider audience in a more permanent form, "Anybody concerned with any aspect of

Human Resource Development will find this book of inestimable value." (*Nadler, 1973*).

Afterward, Knowles differentiated the needs of adult learners from those of juveniles and described the specific methods, which should have been employed: he considered andragogy as a specific theoretical and practical approach, based on a humanistic conception of self-directed and autonomous learners and teachers as facilitators of learning (*Knowles, 1970*).

3.2.2 Workers & Workplaces

The *Worker* started to be considered in its psychological and *individual* dimension (as the collective dimension is evaluated for secondary step); he is an autonomous individual and therefore aspires to *Self-Fulfillment*, in order to grow and realize his *Potential*. Knowles considers physical, growth, security, new experience, affection, and recognition to be basic human needs and describes an educational need as "something a person ought to learn for his own good (cultural dimension), for the good of an organization (economic dimension), or for the good of society (social dimension)" (*Knowles, 1980*).

Adults need to know the reason for learning something and are most interested in learning subjects having immediate relevance to their work and/or personal lives. The needs to implement their skills continuously at all levels in the economic interests of both the company and the worker and, last but not least, the social need to respond positively to the risk of exclusion, deprivation and marginalization (*Knowles, 1984*).

In the professional world, rose the needing of *competence*, the set of individual characteristics that contribute to the effective supervision of a work situation, a performance, an activity. Competence is the ability to orient themselves in certain situations. (*Mc Clelland, 1973*). Adults have a wide experiential base, over time, have accumulated a lot of concepts and a practical approach to learn and operate (*Brookfield, 1995*) so that they directly connect the "Basics" learned examining Reality and often they are not willing to accept uncritically what is being said.

Of course, this approach cannot be generalized, as Knowles noticed "some pedagogical strategies were necessary with adults in some situations – such as when the learner were entering into totally strange new content areas or were learning to

operate unfamiliar machines, especially where Health and Safety were involved" (*Knowles, 1989*)

Knowles suggests that adult human beings are a good deal more complex than laboratory-bred white mice or monkeys

EDUCATION → LEARNING → CHANGE

3.2.3 The Design of the Training

To make the training system an investment, it is necessary to collect data and information for the planning of training; designers should identify both needs of the organization and of individuals (*Dekker, 2014*).

OS&H involves three concepts: complexity, time and multidisciplinarity. The systems are in fact more and more complex, and in this complexity, the experts must find out suitable answers, inevitably complex and not reducible to simple precepts. The time presses the decisions and the design should be completed as quickly as possible: this means that experts should be even faster in identifying and preventing OS&H risks. Finally, OS&H is not anymore considered in a monoculture approach: different expertises are necessary to reach an effective and synergic result.

A spread awareness, in fact, is important because individuals' erroneous assumptions let events go unnoticed or misunderstood and often, rigidities of human belief and perception can lead to a disregard of complaints and warning signals from outsiders. This chain leads to judgment errors, cognitive lapses, deficient supervision and communication difficulties that Safety scientific orthodoxy sees as critical in creating a discrepancy between a safe system and actual system state (*Reason, 1997*). It is important to highlights that a failure is the result of an event chain that Someone somewhere did not anticipate and did not catch something on time. (*Weick and Sutcliffe, 2007*).

From this point of view, professional responsibilities are spread among the workers at different levels, so that decision makers need more training in recognizing the limits of their methods and techniques and they need to find language and concepts to legitimately have a confrontation with low-level workers to reach a better balance between conceptual and material knowledge.

So, managers' education needs an empowerment in decision making under conditions of uncertainty and historical understanding (as individual and

organizational memory), but what it is really important is the empowerment of lower-ranking individuals and reminding them of their responsibilities: the training should inculcate the prevent harm etic and, when the aforesaid ethic is violated, the equitable sanctions (*Feldman, 2004*)

To avoid that incidents and accidents get ignored, covered up or hidden or – at least - get reconstructed so as to align with powerful socio-economic interests, Safety–critical information has to get recognized and shared among parties that would benefit from it.

As Perrow stated "Formal accident investigations usually start with an assumption that the operator must have failed, and if this attribution can be made, that is the end of serious inquiry. Finding that faulty designs were responsible would entail enormous shut down and retrofitting costs; finding that management was responsible would threaten those in charge, but finding that operators were responsible preserves the system, with some soporific injunctions about better training" (*Perrow, 1984*)

To intervene on the population, there are different models of "Health promotion" that authors think could work in the Occupational Safety field.

The most important is "SELF-EMPOWERMENT" approach (also known as the self-actualisation model) seeks to develop the individual's ability to control their own Health status as far as possible within their environment. The model focuses on enhancing an individual's sense of personal identity and self-worth and on the development of 'life skills', including decision-making and problem-solving skills, so that the individual will be willing and able to take control of their own life. People are encouraged to engage in critical thinking and critical action at an individual level. This model, while often successful for individuals, is not targeted at population groups and is unlikely to affect social norms.

Keys approaches are:

- self-help

- The teamwork in which the teacher acts as a resource for the group.

The objective of Safety and Health training is to provide additional knowledge, skills, and attitudes to assist workers in recognizing and taking action to correct hazards in their current work environments.

Stated that in the first three steps, "culture of Safety" designers have to deeply understand and assess the background in which they are going to intervene while,

from this phase, the pivotal point will be the drafting of the training action. Before to start this ambitious program, it is necessary to clarify the basics of workers' education interventions.

Each level of responsibility has its own requirements so, from the PtD phase to the execution time, actors involved must have Competences in the sense of combination of knowledge and skills that enable them to act in a wide variety of situations.

In this light the development of educational actions for improvement always presupposes a preliminary stage of objective assessment of the scenario:

- OS&H problems identification through databases (Occupational Accidents, near misses, ecc..);
- recognition the main cause (computer-aided systems);
- identification of involved people and their learning gaps;
- chose and implementation of correct methodology and suitable models.

It is important to notice that recent analyses of workplace Safety education initiatives for young workers in Canada described approaches as informational rather than instructional and the result was an increasing of knowledge about Safety, but could not be assumed that this knowledge translated to safe behavior and ultimately, injury reduction.

Regrettably, other case histories underlined as applying a generic training program has limited evidence of effectiveness, thus, rose the need of more research focused on attaining a better understanding of how Occupational Safety Education can be made effective in positively influencing not only behaviors, but also individual awareness about OS&H issues.

3.2.4 Evaluation of intervention

As suggested by Ralph Tyler (*1949*), educational approach, should stem from the important concept of having precise and obtainable objectives of each activity, measurable and defined at the outset.

It is important to know that, due to the fast evolution of work situations, some purposes can emerge subsequently to the design and schedule so, to ensure a quality system, the intervention should be developed and delivered continuously taking into account that Safety Competences can occur in any period of people's life or at any stage of their career.

Moreover, to improve the OS&H awareness, every ring of the chain should be considered: to ensure Safety in the whole system, from the first to the last stage of the work, none worker of the site have to be neglected in the top-bottom assessment, but they will be active partaker in a bottom- top view of the approach.

The analysis should aim to:

- Engage and empower actors
- Monitoring tools and procedures
- Spreading the Culture of Safety and sensitivity about the issues and topics of training

The establishment of all objectives should be created using the S.M.A.R.T. philosophy. S.M.A.R.T. is an acronym that is used to guide the development of measurable goals. Each objective should be:

Specific

Measurable w/Measurement

Achievable

Relevant

Time-Oriented

Considering how adults learn, it's necessary to build up directly applicable OS&H training programs:

- Adults are voluntary learners so they should understand the reason and decide they need to learn something, so they will learn needed information quickly because they will realize that the subject matter and the methods are relevant to make their lives easier. If they are experienced, it should be good to encourage them to share their experiences and knowledge. Adults learn more when they participate in the learning process and when they know where they are heading: Adults need to be involved and actively participating in class. Moreover, they learn best by doing, they need to "try-on" and practice what they are learning.

Choice of teaching methods (lecture, cases, simulations, laboratory ...)

1. KNOW - Knowledge Understanding Measurable tests with "theoretical"
2. KNOW HOW - Application Operation Measurable tests with "practices"
3. KNOW Quality- Attitudes Measurable with "observation"
4. Evaluate Learning & Evaluating The System

"*Challenges identified by teachers of occupational Safety included time constraints and the lack of standardization. In terms of teaching methods, our survey, and other studies, suggest that those that are engaging, interactive and face-to-face are most effective. In the face-to-face component, teachers should incorporate case studies and class discussion. The content and delivery mode should be tailored to young workers, taking into account factors such as physical and psychosocial characteristics and, importantly, the situations in which young people are likely to work. In addition, there should be a partnership between schools and industry, such that knowledge and skills introduced at school are complemented and reinforced in the workplace. As recognized previously (Bazas et al., 2002; Schulte et al., 2005), it is important that future occupational Safety education initiatives be subject to rigorous evaluation. Preferably, evaluation should be in the form of longitudinal studies, and in a collaborative evidence-based mode. Outcomes should be evaluated in terms of increases in student knowledge (Bazas et al., 2002), and ultimately in terms of behaviors and injuries*." (*Pisaniello, 2013*).

The approach of IFT interventions often results in a bureaucratic instead of substantiated Safety, a mere formality producing a *paper-based Safety* pasted at the last minute to already completed projects, characterized by:

- ✓ a Person Approach focusing exclusively on the human errors. To blame them for forgetfulness, inattention, or moral weakness is easy, but useless for the prevention. Effective results are possible only through the System Approach, focused on the conditions under which individuals work, to build defenses and avert errors or mitigate their effects;

- ✓ the drafting of generic procedures, "pasted" at the last minute to comply artificially with rules not understood.

3.3 Workers in practice

3.3.1 Rights and Duties of Workers

It becomes important to involve all people of the Organization in the OS&H aspects. Often they operate in a context lacking of a widespread Culture of Safety. That is not in tune with the multidisciplinary research results that would be essential to understand in depth the specific work related Safety and Health criticalities of modern industrial and construction activities, and to identify the suitable countermeasures (*Patrucco, 2014*; *De Cillis et al. 2017*).

According to the Italian Decree April 9, 2008, n. 81, and following amendments, about Health and Safety at Work:

- ✓ *a - Article 2 - Definitions: ... n) 'prevention': all measures or provisions necessary, according to the particularity of the work, experience and technique, to prevent or reduce occupational risks, taken into due account also the Health of the neighboring population and the integrity of the external environment; ...*

- ✓ *b - Article 18 - Duties of the employer and the manager: 1. the employer, who exercises the tasks set out in Article 3, and the managers, who organize and manage the activities according to the functions and responsibilities conferred to them, must ... q) take appropriate steps to avoid that the technical measures adopted to manage the occupational risks can give rise to risks to the Health of the population or a deterioration of the external environment. ...*

In this context, the interrelationship between the Quality of the environment in terms of Occupational Health, and the safeguard of the Health of neighboring population and of the integrity of the external environment becomes relevant.

- ✓ it defines the Worker *"as the person, regardless from the type of contract, operating in an organization for an employer, with or without remuneration".* It is easy to notice that such a definition covers a very wide field, encompassing any type of employment situation, the irregular ones included. Moreover, it ensures to any worker a high degree of protection, formally one of the best if compared to other developed countries;

- ✓ however, the gap among the Occupational Health and Safety regulations, undoubtedly very strict, and the ones for the protection of labor relations has become significant in the last years. This gap results in a decrease of the actual protection level of workers (a simple example is the current difficulty for workers with short period contract to follow an effective program of IFT, as well as to be subjected to careful Health surveillance, in particular if charged of tasks with a high risk profile or involving potentially dangerous equipment).

Even if it is still a long haul, certainly the contribution of Education and Research to spread the Culture of Safety plays a pivotal role.

Nowadays, the common idea is that technicians have the role to draw up the Safety documentation, mandatory for the Italian Decree 81/2008. The 17th article of the decree, lists the mandatory duties of the employer, the duties he cannot delegate:

- the drawing up of *the (DVR) Safety Document*
- the designation of the *responsible of the Safety (OS&H manager)*

This is a key point to define the responsibilities in case of injury or occupational disease, moreover this article underlines as the employer even designating experts to help him in the accomplishment of his duties, keeps holding the responsibility of the workers Safety.

The contents of the Safety document are described in the article 28, whilst the conditions to draw it up in the article 29.

As stated in the art 17, the Employer has to Assess Risks and he can cooperate with the Safety Manager and the occupational physician, "in the cases described in the art 41". It seems that the occupational physician has a secondary role, but the aim of this paper is to stress the importance of his cooperation from the first steps of the Risk Assessment and Management process.

Often the occupational physician intervenes in a second phase, basing his activity on the Safety document, blindly trusting the work of the Technician. It is obvious that the Technician must be prepared, but he can make a mistake in the assessment of the Hazards identification and the Exposure Evaluation. In this case, the whole system would be affected by his errors and the late intervention of the occupational physician would be useless.

The Information Formation and Training topic is stressed by Italian Decree April 9, 2008, n. 81, and following amendments:

- art.2 (Definitions), letter aa) c 1:

"educational process to transfer to workers and other subjects of the prevention and protection system knowledge and procedures related to their roles and duties in the company, useful to reach safer performance and identification, reduction and management of risks"

 "*educational process* "implies different phases. In the training process, the phases generally considered are: detection of the needs, planning, implementation, assessment of the results. Obviously the link between the implementation and the other phases of the" process "must be traced by official and dated documentation";

 "workers and other subjects of the company's prevention system", therefore, not only workers are the beneficiaries of training: the development of skills is seen as a prerequisite for all the people in the company system, including, in addition to the executors of the various organizational provisions, people who perform decision-making and control functions;

 "*knowledge and procedures useful to reach safer performance* ". The learning objective does not end with the transfer to participants of predefined knowledge and models (the "procedures"), but provides them the ability to actively re-elaborate and use this knowledge to acquire new skills. Obviously this re-elaboration should be favored with training activities and organizational development processes that are contextual to the training process.

- art. 37 - Training of workers and their representatives;
- annex I - Serious violations sufficient for suspension of the business activity.

3.3.2 Workers target / Audience

To improve the situation, it is very important to devoid special attention to the aspects of training: at the very first stage of the definition of the processes, the audience has been identified and classified as follows:

- the new entry workforce, more vulnerable to occupational accident risks since they are both young and new to their jobs;

- medium-term employed workforce, still learning and consequently putting a higher attention level in their task;

- the experienced workforce, with already affirmed knowledge, skills and competences necessary to operate independently, but sometimes too confident and consequently not aware of the all the Risks of their activity.

Once the audience has been identified, the next step is to recognize what are the *knowledge*, *skills* and *competences* that every audience need to achieve as determinants of Safety Performance (Griffin et al., 2000).

Moreover, a fourth category is raising. In fact, the third group is growing directly proportional to the ageing of the workforce, in turn connected to the raising of the retirement age. Similar considerations leaded EU OSHA and NIOSH to develop research campaigns on the matter.

In the context of EQF, competence is described in terms of responsibility and autonomy. Applying these concepts to Safety & Health problems at workplaces, would be necessary to identify, analyze the deviations and every gap in the system, and intervene to obtain safer and Healthier workplaces, trying to involve all the co-workers.

Surveys in the United States indicate that 80% of teens have worked since they finish high school. In 2003, an estimated 54,800 work-related injuries and illnesses amongst youth younger than 18 years of age were cured in hospital emergency departments. Given that only one-third of work-related injuries are treated in emergency departments, it is probable that almost 160,000 youths sustain work-related injuries and illnesses each year (*Stephenson, 2008*).

Initial training leads to lower the curve and reduce in particular the consequences in steps 1 and 2; periodic training affects the phase 3.

As shown by the statistical data, accident rates in Europe are still high among young workers. A World Health Organization report (WHO, 2005) highlighted that '*Young workers face the same workplace hazards as adult workers, but are less*

experienced and aware of risks, less apt to ask for and comply with Safety regulations, and less likely to receive technical training'. The strategy of integrating H&S education into education and training general programs developed for 2002–2006, should lead to positive results: it reasserts the importance to take such a peculiar vulnerable category into account as a priority.

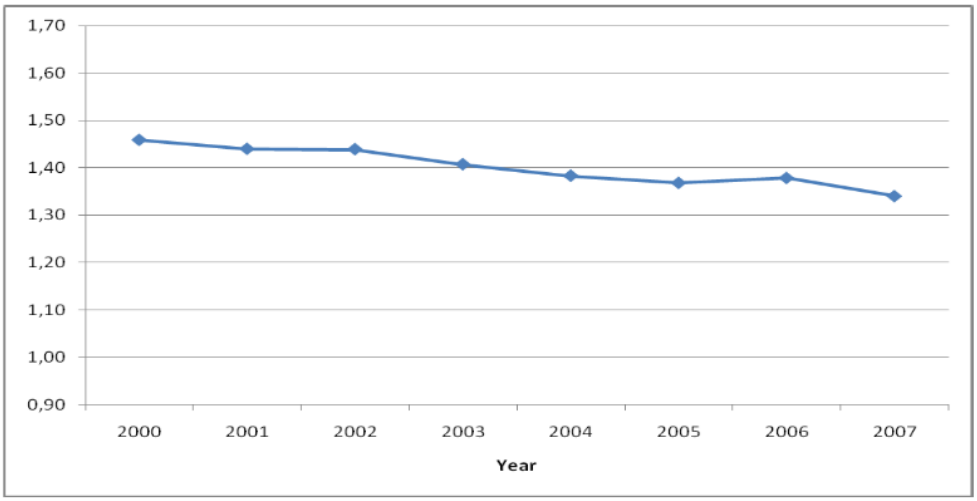


Figure 14 - Ratio of Standardized Incidence Rate (SIR) of workers aged 18–24 to SIR of the total EU 15 active population – source EUROSTAT[2]

Some -certainly not exhaustive- examples of effective approaches are: the education and publication activities of the International Training Center of the International Labour Organization -ILO ITC-, the European Agency for Safety and Health at Work EU-OSHA E-fact examples about companies that involve young people in the organisation's Safety management system, and the Youth@Work—Talking Safety, a curriculum designed by the NIOSH.

ILO ITC - The only tripartite United Nations -U.N.- agency, since 1919 the ILO brings together governments, employers and workers of 187-member States, to set labor standards, develop policies and devise programs promoting decent work for all women and men. Tailor-made programs are offered at the organizational, national or regional level to form in a specific and complete way the experienced technicians.

EU-OSHA - summarized some examples of company practice involving young workers (the typical medium-term workforce) such as:

[2] OSH-and-education-whole-school-approach

- UK energy company E.ON's apprentice training: every three months a skills coordinator takes the apprentice's views on OSH, graduates are required to investigate real-life Safety projects and they are also asked to make recommendations for improvement, helped by apprentice forums;

- German energy supplier, RWE Westfalen-Weser-Ems encourages second-year apprentices to explain their own experiences of accidents and near misses to their newer peers;

- UK construction sector company ROK Construction encourages young workers to face colleagues or superiors with questions or recommendations;

- apprentices of UK construction company Sheldon have regular discussions with the human resources manager, training manager or Health and Safety manager.

- The EU-OSHA E-fact 78 "Involving Young Workers in OS&H" concludes if although these are examples from bigger companies, these types of approaches could be adopted by every organization.

In any case, decision makers involved in the Dissemination of the Culture of Safety should be aware of the evolving Socio-Economic needs, of the evolution of the audience categories and of the possibility of rise up of new ones (e.g. due to aging workforce, as discussed by EU-OSHA "Healthy Workplaces for all Ages"). Moreover, they should consider new Knowledge, Skill and Competence (as "cluster of related abilities, commitments, knowledge, and skills that enable a person -or an organization- to act effectively in a job or situation" defined by European Qualifications Framework - EQF).

As demonstrated, to have an effective dissemination of the Culture of Safety in terms both of contents, methodology and research results, it is necessary a multidisciplinary approach deriving from a synergy between experts in Occupational Medicine, Engineering and other science branches, involving Universities, Public institutions and practitioners.

To point out the best dissemination techniques, decision makers should ensure a multidisciplinary approach in each situation, never forgetting all the links of an

Educational process, from the identification of the audience' cultural background, to the auditors' expectancies and the predefined formation goals.

This screening on the different approaches found in literature, integrated with our direct experiences, is aimed to provide a first step of structured approach to the complex issue of an effective Identification of suitable Educational processes. Creating a methodical collection of Educational campaigns can help people involved in the Information Formation and Training sector, to compare, assess and improve the quality of their activities to define the most suitable in every situation.

Employers should identify the global and specific needs of people involved in the organization - the learners - and their background, the structured courses and the Training intervention on specific Safety issues (deriving from a thorough Risk Assessment).

The final goal is to have an integrated system, resulting in a positive change of the situation, of the behaviors and of the way to face the OS&H matters, not only a huge quantity of paper that demonstrates that some IFT was organized.

To make people change, and consequently to improve the System, it is necessary to make workers aware and keen to participate in this change (the Education Learning Change process).

3.4 School Experiences

3.4.1 The Educational system

The Italian situation of work related accidents and Health impairments is undoubtedly due to a number of different causes, some of them are highlighted in the Second European Survey of Enterprises on New and Emerging Risks (ESENER-2) (http://www.esener.eu):

"Interestingly…, there are significant differences when it comes to the proportion of establishments where risk assessments are conducted mainly by internal staff …: the country ranking changes significantly …".

This does not affect the quality of these risk assessments — in some countries there may be a regulation to contract OSH services for such tasks. However, under the assumption that those controlling the work could easily control the risks, all enterprises should be able to carry out a basic risk assessment with their own staff only.

Moving on to the reasons that motivate enterprises to manage OS&H, fulfilling the legal obligation is reported to be a major reason by 85 % of establishments in the EU-28. There is a positive correlation with establishment size, whereas by country the proportions range from 68 % of establishments in Denmark to 94 % in Portugal. In some countries, particularly those that joined the European Union in 2004 and some of the candidate countries, the driver most frequently reported to be a major reason to address Safety and Health is maintaining the organization's reputation.

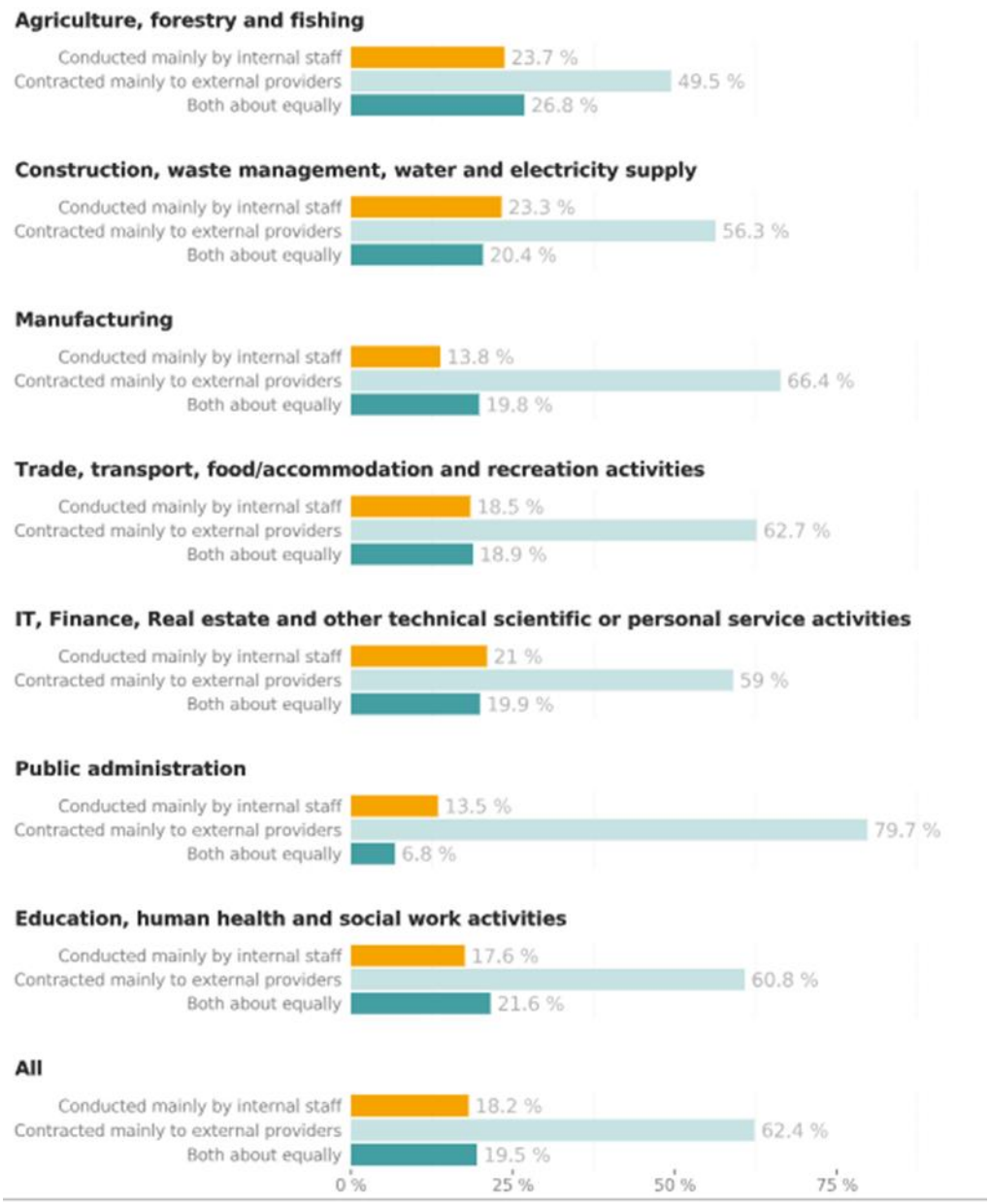


Figure 15 – OS&H conducted by internal/external staff

According to the results of this EU survey in many countries, Italy included, OS&H is considered the task of a limited number of professionals who operate in the field, often adopting personal experience or approaches still inspired by subjective judgement. This context is often not in tune with the research results and lacking of a widespread Culture of Safety.

There is a general incomplete competence of practitioners in every field on the basic principles of a correct approach to the Occupational Risk Assessment and Management.

Concepts of OS&H should be present in schools of all ranks, education should play an important role: the mere discussion of basic criteria and regulatory statements, though necessary, is not enough, and the lectures should cover the innovative aspects in the HI, RA & RM in a Quality approach.

James T. Reason (*2000*), clearly points out that the Safety education should not be limited solely to meet the standards, and intended only to the workers, since effective OS&H conditions require a System Approach based on a thorough Risk Assessment and Management special for the analyzed situation.

Coherently, the Culture of Safety should be the result of an appropriate dissemination in all areas and at all levels, starting from specialized training on Safety Management Systems and high university education, where research special for critical NACE sectors can be developed, together with training courses on the up to date results.

Employers should identify the global and specific needs of people involved in the organization - the learners - and their background, the structured courses and the Training intervention on specific Safety issues (deriving from a thorough Risk Assessment).

As demonstrated, to have an effective dissemination of the Culture of Safety in terms both of contents, methodology and research results, it is necessary a multidisciplinary approach deriving from a synergy between experts in Occupational Medicine, Engineering and other science branches, involving Universities, Public institutions and practitioners.

EU OSHA promoted a Whole-School Approach to stressing the attention on:

- the combination of risk education and the management of Safety and Health in schools - both for pupils and staff;
- the synergy between risk education, Health education, Safety management and the Healthy school concept;
- the involvement of staff and pupils in school Safety process;
- Training and involving teachers in OSH management in their schools, improving their understanding of OSH and developing practical skills, which improves their ability to provide risk education to pupils;
- the development of students' understanding of OSH - even by example;
- involving pupils in hazard spotting and proposing solutions, developing their skills and giving them ownership over school Safety rules;
- Integrating risk education and school Safety and Health throughout the school's activities and the way it functions, to become part of school life, not as an addition or an extra.

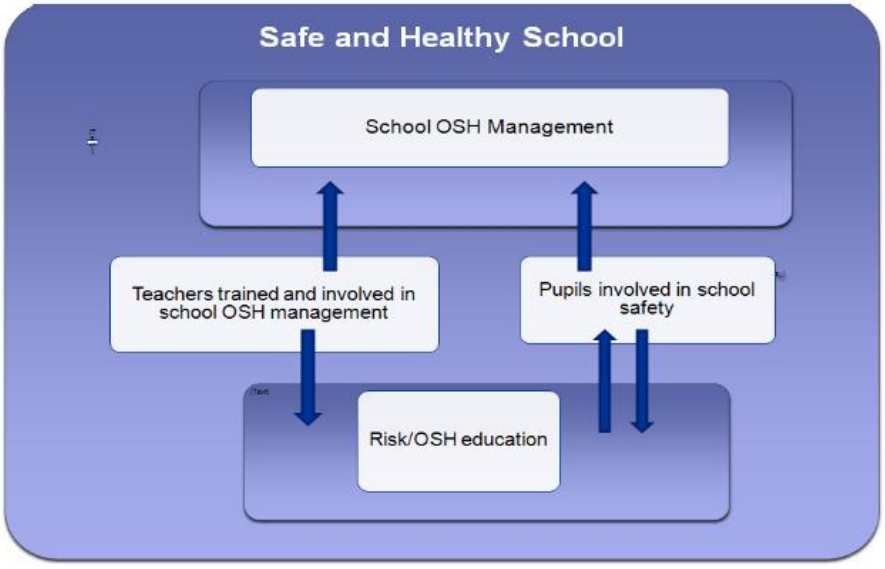


Figure 16 - Model of a whole School approach to OSH - source EU-OSHA.

A dissemination of Safety basics from the beginning of the school cycle of kids, could be a good starting point: everybody is supposed to be a future worker, regardless the career or the scholar level they will reach. In any case, the empowerment of lower-ranking individuals and reminding them of their

responsibilities is important: the prevent-harm ethics, i.e. awareness and knowledge on the OS&H themes, becomes the fundamental approach (*Feldman, 2004*).

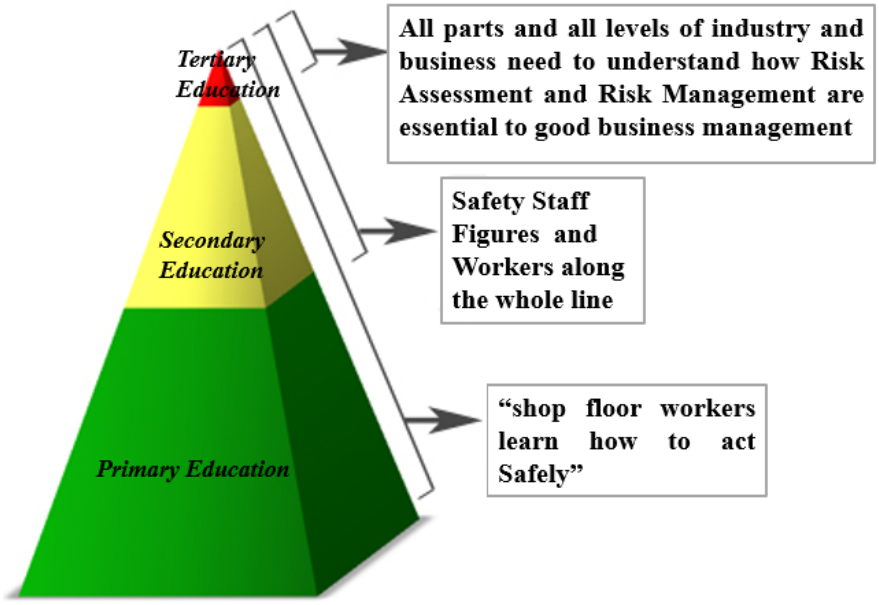


Figure 17 - the importance of OSH matters in the Educational system – source WOS 2017

A survey on educational systems in 20 EU Countries (Italy, however, is missing) and in the United States of America by European Agency for Safety and Health at Work, substantially, highlights the essential role of training in some cross cases provided by special Departments of OS&H- and stresses the following topics:

1- Mainstreaming OS&H into education concerns integrating one policy area -Occupational Safety and Health- into another - education. ... Mainstreaming in relation to OS&H at the workplace is about making risk management principles and 'thinking OS&H' an intrinsic part of the way that actions are taken, so that occupational Safety and Health is not just an additional task;

2- Safety and Health integrated as a transversal topic into degree programs throughout all levels of university education, with it embedded as a compulsory part of curricula. This means that, for example, all engineering students receive some risk education, and that it is not just an optional module or only part of a specialist OS&H and engineering degree…;

3 - like all employers, universities have to run themselves safely and comply with OS&H legislation, requiring attention to be given to the Health and Safety of professors themselves and other staff. Addressing Safety issues for staff and students can be used as a learning opportunity and such a holistic approach is strongly supported by OS&H-education experts…. An explicit emphasis on a safe

and Healthy university environment combined with OS&H education is probably the most effective way to instill OS&H awareness in students.

Substantially, the survey of the European Agency for Safety and Health at Work highlights the essential recognized role of training students in the field of Risk Assessment and Management and of the organization of training - in some cross cases provided by special departments of OS&H.

NIOSH conducts research and praises how to protect these young workers (new entry workforce). To help teachers in middle and high schools to prepare students for safe and Healthy work, researchers with the NIOSH Safe-Skilled-Ready Workforce program and their partners developed a curriculum called Youth@Work-Talking Safety. Talking Safety is free, tailored for all U.S. states and territories to reflect local child labor laws and resources, and it supports current educational standards. Through Talking Safety, young people learn foundational knowledge and skills in workplace Safety and Health, the NIOSH 8 Core Competencies.

These competencies are transferable to other life domains, portable through all jobs and industries, and they help students form a solid base of Safety knowledge on which job-specific training and skills can be putted up. (*Howard, 2016)*.

On May 2015, Miami-Dade County Public Schools (M-DCPS) built skills for safe and Healthy work into the mandatory content to be covered in all eight-grade science classes, which will reach just about 17,000 teens each year. (*Howard, 2015*).

In the M-DCPS, eighth-grade students received training on Talking Safety in their science classes. Pilot results from more than 1,650 study participants indicate substantial shifts, pre- to post-test, in eighth graders' knowledge and approaches about workplace Safety and Health, and self-efficiency and social intentions to use the skills they learned through the program.

NIOSH and its partners, including the Labor Occupational Health Program at the University of California/Berkeley, the Massachusetts Department of Public Health, and the Education Development Center Inc., first designed Talking Safety almost three years ago.

Stakeholders across the country have since championed it and continue to be important partners in its dissemination.

In Italy, this topic is rising importance due to the alternation between school and work, mandatory for all students attending the last three years of high school, is one of the most significant innovations of law 107 of 2015 (The Good School) in line with the principle of open school. It is a cultural change for an Italian dual system, which incorporates good European practices, combining them with the specificities of the manufactories and the Italian socio-cultural context.

“School-work alternation” is an innovative teaching method, which through practical experience helps to consolidate the knowledge acquired at school and to test the attitudes of students in the field, to enrich their training and to orientate their studies and, in future work, thanks to projects in line with their study program.

Of course the Operational Guide of work-school alternation activities deals with the topic of Health and Safety of students in the host structures by reiterating what has already been explained by the Inail – MIUR) Ministero dell'Istruzione, dell'Università e della Ricerca) Handbook "Management of the Safety system and culture of prevention in schools" (page 233). The specific training will have varying duration, depending on the NACE sector of the hosting Company and the related risk profile. According to the Italian Decree April 9, 2008, n. 81, and following amendments, article 37, paragraph 1, is the responsibility of the employer, identified in the host, who knows the risks related to the tasks and the possible damages and the consequent measures and prevention and protection procedures characteristic of the NACE sector of the company. If the hosting Employer is not able to provide specific training, it can delegate the school to impart it in relation to the risk assessment of the assigned tasks, the machines and equipment to be used, and the expected exposure time. The conditions and the responsibilities of the training are defined within the framework of the agreement signed between the school and the hosting company.

The document stresses the importance to integrate OSH into university-level education as promoting a Culture of Safety in the workplace is not just about ensuring that shop floor workers learn how to act safely. In fact, the actual OSH legislation is goal-setting and follows risk-based approach – risks must be assessed and appropriate measures put in place. Everybody industry and business - regardless the role, the levels - needs to understand how risk assessment and risk

management are essential. *"Future designers, architects, engineers, finance officers, doctors and other Health professionals and managers and supervisors at all levels, right up to the director level, are among those who need relevant education about their future OSH roles and responsibilities".*

Practitioners do not need to be omniscient, the careers are not comparable and interchangeable, rather they are complementary, and a strict cooperation in Safety matters could lead to a mutual control, resulting as an enrichment for all the figures.

The dissemination finds important allocation at the University education stage. The cooperation programs involving Universities and top managers lay at the very base of OS&H improvements, particularly in critical NACE sectors. Managers' education needs an empowerment in decision making under conditions of uncertainty and historical understanding (as individual and organizational memory), and in communication capabilities also towards low-level workers.

3.4.2 Politecnico di Torino

Politecnico di Torino deserves a special mention, for both the cultural and economic effort towards OS&H improvements, even if more in terms of workers Safety than in putting into effect of the aforesaid Education principia in the courses. Even if the importance of education on OS&H is clearly understood at the Rectorate level, some cultural gaps remain in medium level bureaucrats.

Politecnico di Torino provides general information and engineering-readiness skills focusing on some core competencies for postgraduate students, employees and practitioners operating in the field of OS&H. It provides OS&H topics and discussion, Computer-aided systems as support in the analysis of scenarios, research projects about the advanced techniques for the analysis of accidents. Moreover, in cooperation with expert Occupational Physicians, Environment and Workplace Prevention Techniques from Università di Torino, and some experts of National Boards operating in OS&H field, Politecnico contributes to the dissemination of the Culture of Safety with courses organized for different categories of students. The offer includes classes from 1st (BSc) and 2nd (MSc.) up to 3rd (PhD) level, and Masters and refresher courses for new entry and medium term employed workforce and practitioners or Inspectorate technicians operating in the field of OS&H.

The course structure divides in frontal lessons and solve some Problem Based Learning PBL exercises. was originally conceived approximately in the 1980 (*Barrows & Tamblyn*) – it is an alternative method of learning which stimulates the students to test their skills of management and organization within a working group, cooperating as a team to develop the skills of problem solving, under the constant supervision of tutors.

The topics and their scheduling in terms of both time and discussion of theoretical aspects and practical developments, besides responding to the Dublin's descriptors, are in line with the Italian official requirements[3].

Education can play a pivotal role, and Universities, thanks to their nature of teaching and research institutions *(In terms of attention and comprehension capability of the results of applied research on the topics of OS&H, as discussed e.g. in (Borchiellini et al., 2018)*, can make the difference. Moreover, engineering research and development can implement innovative design, and quality and Safety concepts for stakeholders, at the launch of new projects of national and international interest.

3.4.3 Promotion

The International Meeting "the basic role of the purchasers of great infrastructural operations in the promotion of the Culture of Safety: management and communication strategies, contractual aspects, case histories and best practices" (Turin, Politecnico, May, 12th, 2017) organized by Higher Institute on Territorial Systems for Innovation - SiTI, with the cooperation of the research team of The General Safety Issues and Goals in Turin Universities -TGSIGTU, and of Geoingegneria Ambientale e Mineraria, was an important occasion of debate between "insiders" on the approaches and experiences on OS&H in relevant infrastructures, focusing on the excellences, with obvious return of, dissemination of the Culture of Safety.

[3] Italian Decree April 9, 2008, n. 81, and following amendments, -enforcement of the 92/57 EEC Directive- Annex XIV: minimum content of the 120h training course for Coordinator for safety and health at the project preparation stage, and Coordinator at the project execution stage

The meeting became a real chance to collect firsthand information and spread the results, the innovations and the original approaches to purchasers and contractors, designers, and qualified OS&H practitioners and experts.

It was not supposed to be an *una tantum* occasion, aimed at mutual exchange of information on the possible improvements of Occupational and Community S&H.

In fact, it was the first of a series, the following year, the Higher Institute on Territorial Systems for Innovation - SiTI organized a second edition divided in two days: “Eras of OS&H Development from early ’50 to industry 4.0” and “Innovation in tunneling and tunnel use: improvements and criticalities in Safety and Health”.

The International Meeting held in Turin, Politecnico, May, 23rd and 24th, 2018, with the cooperation of the research team of The General Safety Issues and Goals in Turin Universities -TGSIGTU, and of Geoingegneria Ambientale e Mineraria, was another important moment to share the knowledge and innovative techniques gained so far.

Table 3 - Promotion of OS&H - other initiatives

Table 4 -- Dissemination through OSH journals and Conferences

	 ICheaP13
	
	
	

3.5 In closing

In the first (technological) age, accidents were prevented by following technical standards and guidelines, because they were largely attributed to mechanical and structural failures. In the second age, causes were found in human behaviors and human errors. In the third age rose the realization that human performance is based on a complex interactions of the socio-technical system that constitute an organization and that humans were rarely the sole cause of accidents or error. In the following age, the fourth, poor organizational and cultural factors are recognized to play a key role in most accidents. Nowadays, that the research in engineering, management, psychology and sociology and leadership is rising: culture and collective mindfulness are more advanced strategies for managing Safety complexity and uncertainty represent the fifth age where people- thanks to their ability to adapt - play a key role in the proper functioning of modern technological systems.

Educational processes result precious for a correct dissemination of the "Culture of Safety". As seen, the goal is to transmit information to all the workers, regardless to their previous knowledge and background. These strategies drew from

disciplines, for example ecology, human factors, management and psychology. Technological and behavioral strategies represent contemporary approaches; socio-technical and cultural and resilience involve more sophisticated approaches. A large number of Educational approaches have been analyzed, stressing strengths and weaknesses, not in absolute terms, but taking into account the related typology of audience. Workers have a wide experiential base, over time, they have accumulated a lot of concepts and a practical approach to learn and operate (*Brookfield et al., 1995).*

Figure 18- interventions of education addressed to different targets

Chapter 4

Case Studies

Does a general effective approach exist, or it is necessary to develop a peculiar one in every situation?

Only a substantial enhancement of the Culture of Safety can help to realize a correct Risk Assessment and Management (RAM) involving a multidisciplinary approach, founded on technical and technological feasibility studies, considering the development in scientific and technical knowledge.

Analyzing the data, there is no lack of tools to effectively set up activities in full compliance with the principia of both European OS&H Directives, and good systems efficiency, based on optimized systems design and management. Also the often demanding task of projects quality review can result simplified where a well-tested approach, consistent with the OS&H Standards, and points out how the absence of a rigorous analysis of the whole aspects characterizing a job or a NACE sector may lead to negative implications of the OS&H.

Indeed, there are approaches that can contribute to identify and criticize the misleading results in poor Occupational RAM procedures, contributing to the dissemination of the Culture of Safety, both in the design and in the audit phases.

The definition of *work* and *workplace* is evolving day by day, innovation goes fast than Regulations, experts in sport techniques or artistic fields are hired in special activities to operate in exceptional situations: a new interest in how to reconcile the performances of every kind of workers in an OS&H perspective is rising among bright technicians.

As described in the previous chapters, the Culture of Safety - and its dissemination are extremely flexible and adaptive to every kind of situation and if well applied can avoid the most common causes of imprecision in RAM - incompleteness, subjectivity and excess of optimism – not to affect the result.

An analysis by NACE sectors in the EU-28 between 2010 and 2015, reveals that "*the largest reductions in fatal accidents at work were recorded (perhaps*

unsurprisingly) for activities that already had relatively high numbers of fatalities: the overall number fell by 575 during the period under consideration".

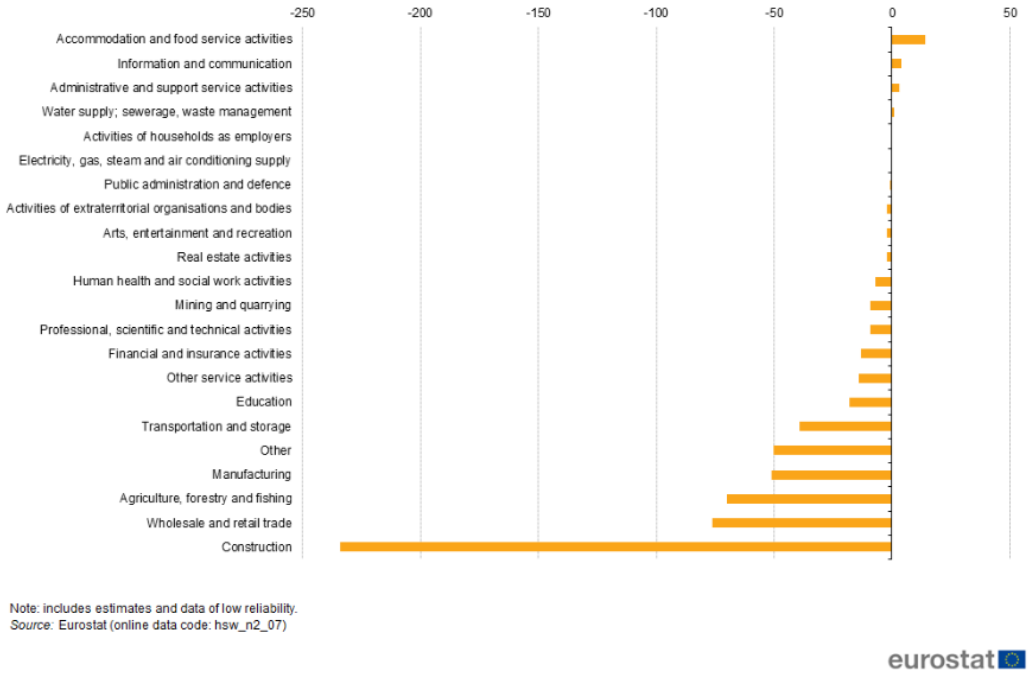


Figure 19 -Overall change in the number of fatal accidents at work, by NACE section, EU-28, 2010-2015 (persons).

In particular, the number of fatalities in the construction sector, decreased by 234; the next largest reductions were recorded for wholesale and retail trade, for agriculture, forestry and fishing, and for manufacturing.

By contrast, there were only four NACE sectors until now considered "safer" where the total number of fatal accidents at work increased between 2010 and 2015.

Actually, analyzing the situation, it appears clear that the rate of the fatalities in Europe has not seen a decrease as shown in the following diagram.

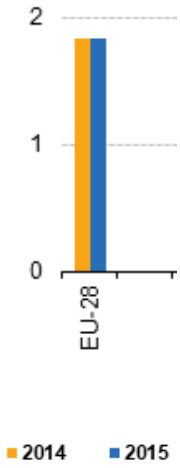


Figure 20 - Fatal accidents at work, 2014 and 2015 (incidence rates per 100 000 persons employed)-source AAW2018.png

The result is that probably the decrease of fatalities is a direct consequence of the decrease of number of workers, so it is not considerable a good news anymore: *"accidents in particular years are likely to be related, to the overall level of economic activity and the employed in this sector, affected by the contraction in overall levels of economic activity".*

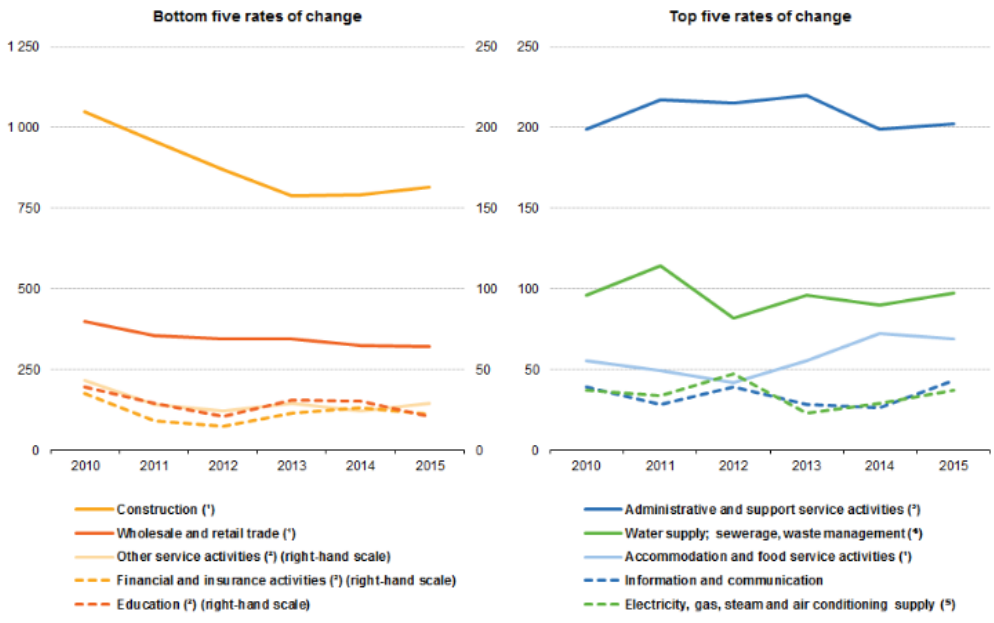


Figure 21 - Development of fatal accidents at work — highest and lowest relative changes, by NACE section, EU-28, 2010-2015 (persons)-source AAW2018.png.

However, a picture of the situation can be obtained analyzing in depth the incidence rate, information that takes into account the number of workers avoiding affection in the data by external variables.

Although all the NACE sectors are described in the above Tables, the concept of simplification recurs: all the activities in fact merge in macro "divisions", supposed to describe all the characteristics of the different micro activities. Of course, analysts can find situations, whose the NACE sector is not in the spotlight, totally missing of peculiar regulation and good practices.

Within the Università di Torino program "Environment and Workplace techniques", some specific examples linked to well-known sectors both notoriously characterized by high rate of injuries at work and unfamiliar to the analysts have been analyzed.

As seen in the following diagram, the distribution of workers in the upper income countries is fragmented and, despite the simplification of NACE sectors, complex.

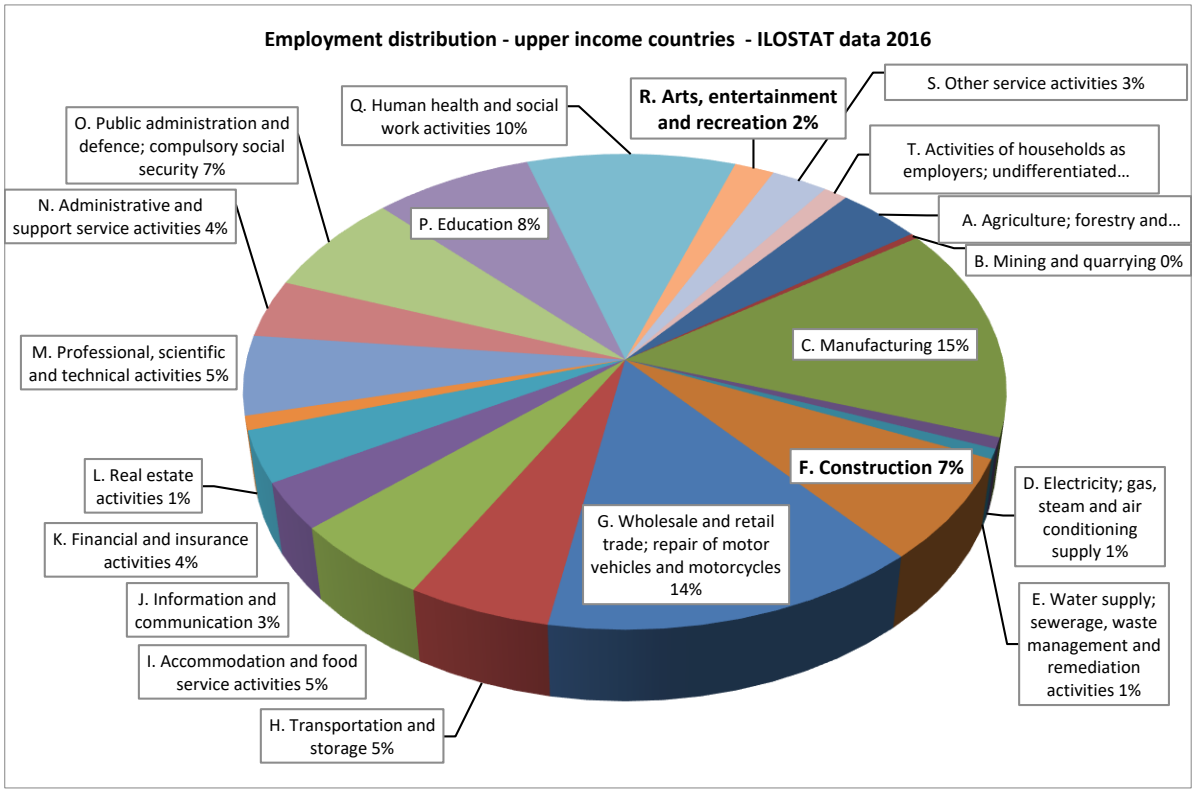


Figure 22 - Employement distribution - upper income countries - ILOSTAT data 2016

The diagram represents the distribution of 483.740.000 workers4 in 2016; some cases taken into account are sub categories of the area of Construction (F. 7%) – totally employing 34.690.000. Others are connected to the artistic/show world (R. 2%), where performers are often considered as artists, neglecting they are practitioners, assembling, performing or maintaining a stage that is full-fledged their workplace, situation regarding 8.548.000 of workers.

So different scenarios emerge, we analyzed some of those lacking of peculiar and effective regulations, often in those cases where to "simplify", the job is assimilated to a similar one, and that brought some considerations on the "simplification of the analysis", typical of widely used qualitative approaches, highlighting the consequent shortcomings, and the deriving over/underestimation of the risks.

"Prevention through Design" (National Institute for Occupational Safety and Health (NIOSH), and Quality management of the Design implementation can control the causes of injuries and Health impairments at the workplaces: considering the OS&H since the very first feasibility and design steps impedes a series of compromises, and the resulting poor Safety level. Moreover, special care was necessary along the actual Design implementation, to keep efficient and improve the planned Safety measures.

This involved a cultural changes: a detailed knowledge of the situation, and a throughout Risk Analysis of the possible project options and of their future implementations. To get rid of subjective evaluations on consequences and probability of occurrence of such events, involving slapdash remedies. Occasional inspections limited to the last phase are clearly inadequate to highlight and control the criticalities of complex activities.

A Quality approach to OS&H, e.g. according to the ISO 45001 standards, may nowadays grant efficient pro-active results. Since 1989, the EEC 89/391 Directive

[4] "The employed comprise all persons of working age who, during a specified brief period, were in the following categories: a) paid employment (whether at work or with a job but not at work); or b) self-employment (whether at work or with an enterprise but not at work). Data are disaggregated by economic activity and occupation, according to the latest versions of the International Standard Industrial Classification of All Economic Activities (ISIC) and International Standard Classification of Occupations (ISCO), respectively. Economic activity refers to the main activity of the establishment in which a person worked during the reference period and does not depend on the specific duties or functions of the person's job, but on the characteristics of the economic unit in which this person works. Information on occupation provides a description of the set of tasks and duties which are carried out by, or can be assigned to, one person."

introduced the Risk Analysis as a mandatory task for the employer: Art.5. *The employer shall have a duty to ensure the Safety and Health of workers in every aspect related to the work,* anticipating the concepts discussed above.

In the following sections have been listed a series of NACE Sectors analyzed in their peculiarity and, after a complete Risk Assessment and Management, some specific solutions have been purposed.

4.1. Infrastructures

Infrastructures are part of the critical NACE sectors but, despite of their final intended use, money spent, workers involved…, they are important for the improvement/ replacement of existing systems, as *real technical and technological challenges, and a moment of development and evolution of the whole national system during the years, and across all phases from design to execution* or introduction of new sites of interest. The examples analysed were a chance to see key works, of interest not only of the Countries hosting them, but, more often, responding to an international interest within the European community. *All the great works represent the answer to social and economic needs: goods to move around Europe increase day by day and road transport could not satisfy the need for many reasons such as related traffic, environmental pollution, hazard factors connected to intrinsic and extrinsic variables.*

A glance to the observation data from Bankitalia, Italian Statistical Institute – ISTAT and Eurostat shows that in the lapse 1980 – 2010, economic resources in Public investment in Italy has been the 2.6% of the GDP (Gross Domestic Product). In 2008 Italy invested in infrastructures €18.9 billion (beginning of crisis), in 2015 € 12.2 billion, in 2016 € 13.47 billion and in 2017 € 16.8 billion (forecasted). To confirm that statement, it is sufficient to compare those investments, for example in 2015, with the amount of public and private contribution invested in Research & Developments: € 22.9 billion (€ 8.9 billion from public contribution). Great works always demand to overcome the technical limits and introduce innovations and, involving substantial investments in Research & Developments, can then be an important occasion of cooperation between purchasers and research institutions ([5]).

Some virtuous experiences, concerning completed or ongoing situations gained by important purchasers (Figure 23), became a real chance to collect firsthand information and spread the results, the innovations and the original approaches to clients, contractors, designers, and qualified OS&H practitioners and experts.

[5] note: Safety is a *scientific* system of organized and systematic knowledge production, i.e. the unity of *actors* (research groups on techniques, technologies and OS&H topics) that conduct *researches,* and, through complex *structures* (journals, papers, books, meetings, ...), spread the gained knowledge at different levels to create an *educational system* (Aven, T., 2014): as discussed in DeCillis et al. 2017, Politecnico di Torino, thanks to its widespread technical - technological expertise, integrated with confirmed OS&H competences, can then be a prestigious reference Institution.

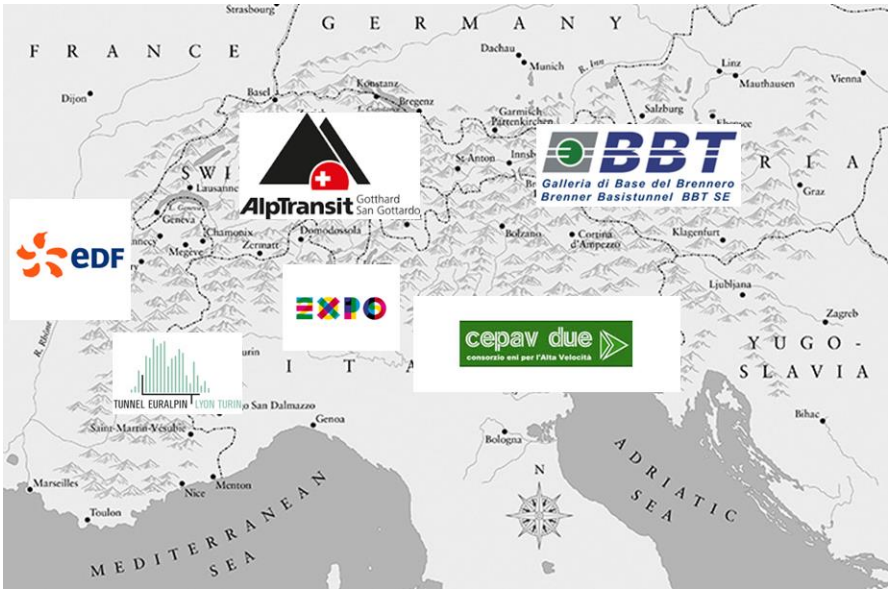


Figure 23 - the relevant Great works in Northern Italy discussed

Far from a mere report on the work executed, it is provided a critical analysis of the main results in terms of effective contribution to the dissemination of the Culture of Safety, in particular on technical and managerial approaches adopted by each infrastructure analyzed, highlighting the original innovations.

4.1.1 The Case Histories

Infrastructures do not result only in mere figures regarding kilometers of tunnels, bridges, money spent, workers involved…, but they have an intended use aimed at the improvement/ replacement of existing systems, or introduction of new sites of interest. The following *key works*, of interest not only of the Countries hosting them, but, more often, responding to an international interest within the European community. The following seven Tables (5 – 11) summarize the main information about the infrastructures analyzed.

An overview of the European community highlights the essential role of the following infrastructures to connect Italy to the border countries, getting through the Alps in order to make easier the circulation of goods, people and resources.

There are similar situations in the cases of the Switzerland Gottardo, realized by Alptransit and already opened, together with the minor but not less important work of the Ceneri Tunnel.

On the eastern borders of Italy, between Trentino and Austria, there is the Brennero Tunnel put in the corridor between Scandinavian countries and the

Mediterranean sea, the Treviglio Brescia High speed railway to connect from east to west the north of Italy and, consequently, to enforce the transversal European axe from Portugal to Ukraine. Even the Turin Lyon tunnel will be put in this ambitious program even if works have just begun yet, the project is included in a bigger net of railway system.

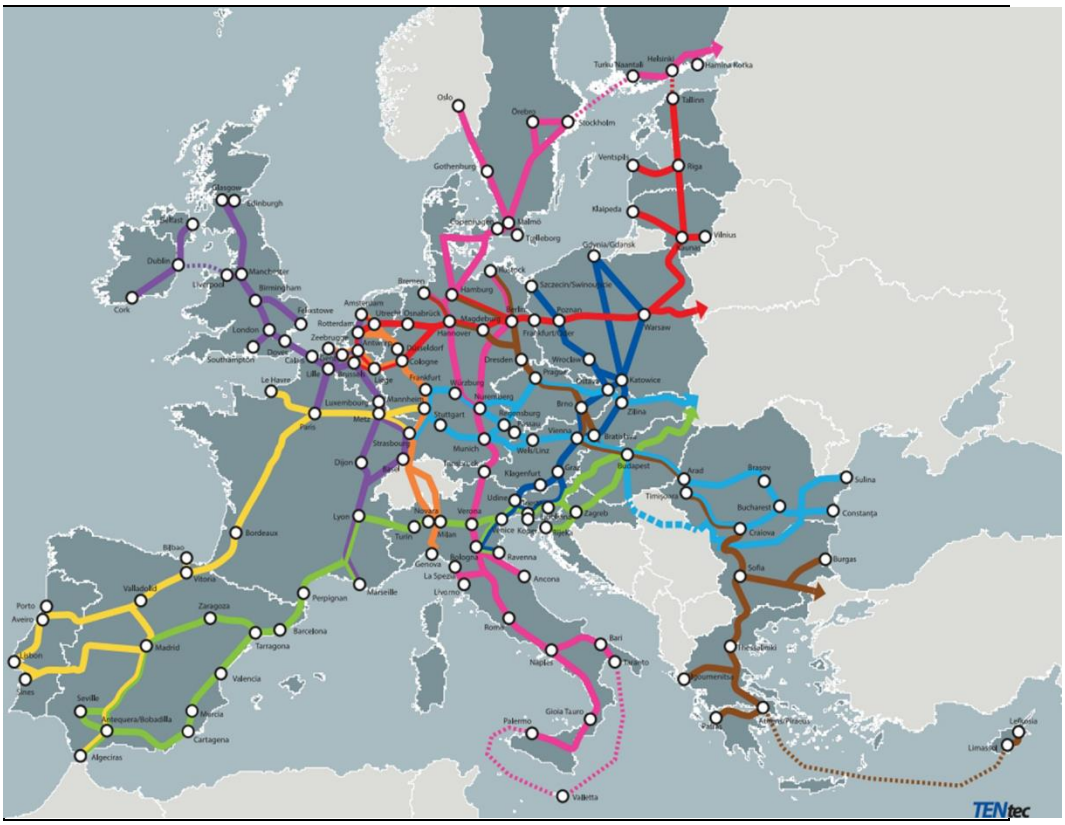
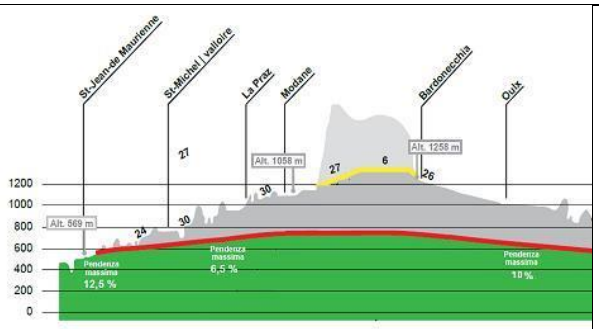
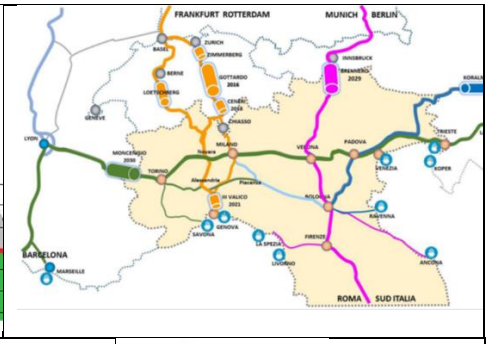


Figure 24 - The Core Network Corridors - source Mobility and Transport, European Commission

Table 5 - - Lyon-Turin Base Tunnel





TUNNELS	MONCENISIO	FREJUS
Investments €	8.6 M €	
Workers involved	n.a.	n.a.
Year of completion	2029	1871
Length	57,5 km	13,64 km
Time required	1h 47	3 h 43 min
m above sea level	474-569 m	1190-1335 m
slope of the path	6,5 – 12,5 ‰.	27,5 - 30 ‰
trains max length	750 m	550 m
Locomotives	1	3
Convoys Weight	1600 t	Max 650 t
Freight train speed	Max 100-120 km / h	
Passengers train speed	Max 220 km / h	

TUNNEL EURALPIN LYON TURIN

Mediterranean Trans-European Network Corridor

Table 6 - Milan- Verona railway

New High Speed / High Capacity Railway Milan Verona - Functional Lot TREVIGLIO – BRESCIA

cepav due consorzio eni per l'Alta Velocità

Co-financed by the European Union Trans-European Transport Network (TEN-T)

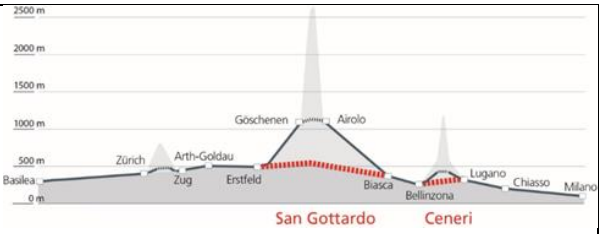
RAIL FREIGHT CORRIDOR 6

Mediterranean Trans-European Network Corridor which will link southwestern countries to Eastern Europe, the Mediterranean Corridor is a privileged itinerary for both Asia and Europe (from Spain to Ukraine)

Investments €	$2\ 10^9$ €
Workers Involved	More than 5000 – $4.5\ 10^6$ h worked
Year of completion	2016 – in 5 years
Length	51 km
Total trains/day	1 / day to Rome/Naples
Passengers train speed	200 km / h
Time required	-16 min than before

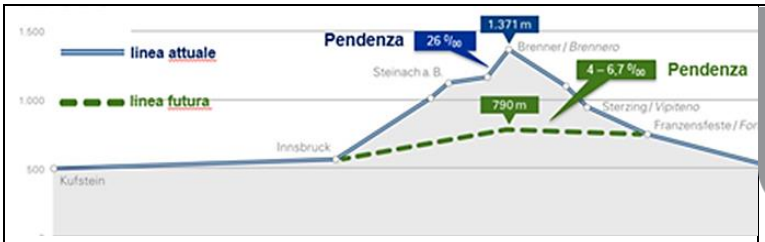
Table 7- Rhine-Alpine Core Network Corridor

Rhine-Alpine Core Network Corridor, connecting the North Sea Port of Rotterdam to the Mediterranean basin in Genoa, crossing a strong economic area whose gross domestic product (GDP) accounts for 16% of EU GDP.



TUNNELS	GOTTHARD	CENERI	PREVIOUS
Investments €	3.3 10^9 €		
Length	57 km	15.4 km	15 km
Workers involved	1.800		
Year of completion	2016	2019	1882
Maximum depth:	2.300 m	800 m	
m above sea level	550		.1150
slope of the path	12.5 ‰.		
Freight trains/day	250 - 260	390 total	290
Passengers trains/day	50 to 80		
Convoys Weight	4.000 t		2000 t
Passengers train speed	200 km / h	Notes: less locomotives, less personnel, less electricity.	
Freight train speed	100 km / h		

Table 8- Scandinavian-Mediterranean Core Network Corridor



Scandinavian-Mediterranean Core Network Corridor

Tunnel	Brenner	Previous
Investments €	3 10^9 €	
Workers involved	n.a.	n.a.
Year of completion	2025	1867
Length	55 km	75 km
Travel Time	35 min	1 h 45 min’
m above sea level	790	1.371
slope of the path	4 – 6,7 ‰.	26‰.
Total trains/day	400	*290
Trains’ length	750 m	450 m
locomotives	1	2-3
Convoys Weight	1.600 t	1.200 t
Freight train speed	100 km / h	Notes: less personnel less electricity
Passengers train speed	200 km / h	

A different opera is the yard Romanche Gavet located thirty kilometers far from Grenoble on a stretch of the Romanche, with a steep drop in altitude. The river has been exploited for a century by industrialists and right now EDF is implementing

an ambitious project which consists of replacing six existing centuries-old power stations with a more powerful, and more environment-friendly underground powerhouse that will enhance the river Safety, reducing the environmental impact and enabling the development of the territory.

The new opera consists of a movable dam with 3 valves, a water intake, a 10-km long gallery, an armored vertical well, an underground plant with 2 groups and a Cave for transformers. To absorb water hammer blows and hydraulic intumescences, an equilibrium chimney is positioned at the end of the downstream section of the gallery.

It was also designed a dissipative structure to evacuate the water filled with its energy in the event that a group triggers and is damaged.

In this case, the direct impact of the infrastructure is substantial: with the same flow and the same height of water will be produced 10 MW more or 155 GWH additional (enough to supply the need of a city of about 70000 inhabitants, equivalent of the neighboring Chambéry, Alpine town twinned with Turin).

Table 9 - Global project Romanche- Gavet

Romanche Gavet - EDF is replacing six existing centuries-old power stations with a more powerful underground powerhouse

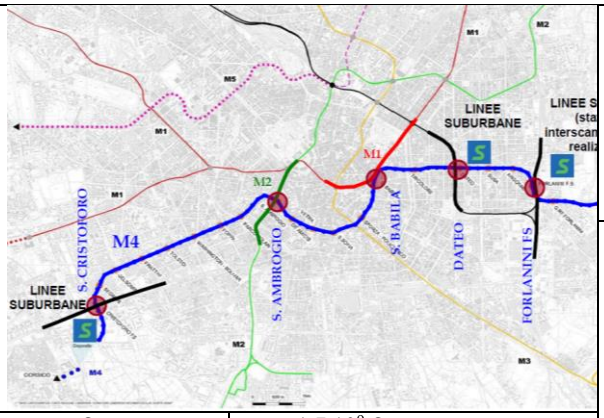
Investments €	
Workers involved	
Year of completion	2022
Power – Production increase	10 MW - 155 GWH vs previous sitiation (*)
Length	10-km
Structure	2 groups
	1 Cave
Notes: (*) need of a city of about 70.000 inhabitants	

Other great works had (or will have) important impacts on one of the most important Italian city, Milan: the fourth line of Underground (M4) and, of course the International Exposition hosted in 2015.

Both are great works that had to face many interferences due to the frenetic life of a big metropolis as our economic capital is.

Although the realization of the first one infrastructure involves inconveniences analyzed in the following chapters, it is more than obvious the benefit that it will bring to the traffic of vehicles and people in 2022, when the inauguration is planned.

Table 10- Fourth line Milan Underground (M4)

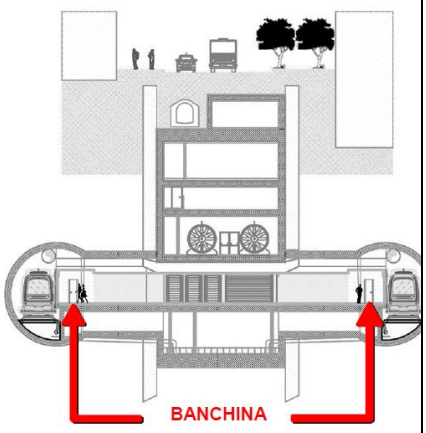


Investments €	1,7 10^9 €
Workers involved	n.a.
Year of completion	2022 (88 months duration)
Length	15 km
frequency of a train	90 s
Stops	21 stops
Interconnections	6
Passengers per year	86 million
Passengers trains speed	80 km / h

Notes: less traffic of surface vehicles

ano

Fourth line of Underground (M4).
Connect East and West side of Milan – straight to the airport.



EXPO 2015 faced similar problems with the substantial difference that it needed to be completed in a short time with a high number of companies involved to realize variegated/diversified projects in limited space and time (233 Coordinate Subjects on a Site Surface of 1,100,000 m2 in almost 6 months)

The average of presence at the yard between November and April 2014 was 3,362 people with a peak in April 25, 2015 – one week before the opening - of 9,147 people.

Table 11- EXPO Milan

Investments €	2,2 10^9 €, 3,2 10^9 €

Enterprises	233 Coordinate Subjects
Site Surface	1.100.000 m^2
Average workers in the yard	November/April 2014: 3.362
Max. workers in the yard	April 25th, 2015: 9.147
Year of completion	2015
Time required	6 months
Total visitors	22,2 10^6
€ from visitors	421,3 10^6 €

4.1.2The Culture of Safety in practice

The considerations cover the main topics discussed in the 2nd chapter and are organized coherently with the result of the critical effort to classify and organize the different sub-topics of the Culture of Safety.

a) Value of the Culture of Safety dissemination (in compliance with the OS&H Regulations and Standards), and Occupational and Community S&H criticalities:

The reports on injuries occurred in the yards, underline the importance to carefully understand data before to plan corrective measures. In every site, the number of accidents alone is unusable, if no information about presence in the site attendance is available: great works are characterized by continuous variability in the number of workers due to the simultaneous presence of a number of enterprises during the various execution phases. At the same time, the severity of the consequences should be considered, to sort hierarchically the Risky processes, and immediately intervene where necessary.

This is a typical criticality of temporary and mobile construction sites**,** and, hence, it is important a continuous action of dissemination of the Culture of Safety.

b) The need of specific competences in techniques, technologies and OS&H, and the role of decision makers:

Great works and infrastructures are important as real technical and technological challenge, and they result in a development and evolution of the

whole national system during the years, and across all phases from design to execution. All the great works represent the answer to social and economic needs: goods to move around Europe increase day by day and road transport could not satisfy the need for many reasons such as related traffic, environmental pollution, hazard factors connected to intrinsic and extrinsic variables.

It is moreover important to consider that in a Prevention through Design – PtD approach, every intervention has to be a good forward-looking investment to make the whole system working smoothly avoiding waste of time and resources. In this optic, the solution of the problem of an integrated design, covering the Safety fittings necessary in the execution phase, and their possible use for the final destination also. Designers must project some intervention to ensure the highest reachable OS&H level in the execution phase, suitable also to respond to future use.

c) Culture of Safety at all levels, and Goals to reach in terms of basic knowledges/competences of workers and other actor:

In the case of tunneling operations, the need to minimize the risks from the very beginning of the design process is of paramount importance. Safety cannot be developed in a compartmentalized approach, and pasted on an already complete project, but it has to match phase by phase all the process steps, from the design to the emergency management. Thus it is necessary that every professional involved in the work is familiar with the basics of OS&H.

In this optic, some purchasers involved special teams of external engineers, experts in OS&H, and projects were then submitted to a group of verifiers. Others, due to the characteristics of the underground infrastructure, decided to afford a geognostic exploration to improve the knowledge of the rock formations, to refine the design. Designers, of course, had to consider also practical aspects: the deep intercepted fossil water, the amount of muck to manage, the supply materials for the work progression, etc., and, to avoid the increase of the traffic load of public roads connecting to the tunnel, they realized secondary tunnels to face all the problems above mentioned, minimizing the possible negative consequences.

It is obvious that not every practitioner is required to be OS&H expert, but one of the pivotal aspects necessary to ameliorate the Safety situation is that workers develop knowledge, skills and competences coherently to their expertise level and decision making power.

d) Find target

The considered infrastructures differ at first for the geographic area where they have been designed and realized or programmed. Every case had to face different problems and different challenges: Regulations are different not only for the typologies of infrastructures, but they also depend from the Country where the same are realized, or, this being the case of Italy, also from Regional rules. It is necessary to carefully consider these aspects, in particular in infrastructures (usually tunnels) connecting two Countries (for example, Switzerland has obviously no obligation to transpose the 92/57/EEC Directive; the Sud-Tirol region has different supervisor's bodies compared to other Italian regions, etc.). In these cases, all the Official bodies have to coexist, and the only possible (and Safe) solution is to copy the strictest rules of both the Countries, reaching a situation of compliance, independently of both the exact position where the yard is located, and the progress of the operations.

e) Subjects and organizations involved

For all the infrastructures, the commitment deals with the Public Administration, so that works have to undergone specific control commissions that confirm the suitability of the selected contractors. The contractors have different organization charts, internal associations, business relations, numbers of purchasers or contractors, etc., but, in every case, it is evident the need and the importance of simplification ([6]). Simple Systems are – in general - easier to control and monitor, but not only: it will be also easier to manage an educational system having a clear distribution of roles, without any confusion about duties and responsibilities in OS&H matters.

Most of the great works face the problem of interferences: managers must identify the coexistence of more than one enterprise operating in different fields at the same time and in a limited space. It is important to fix these criticalities from the design phase, using all the tools useful to avoid incompatible operations overlaps.

In many cases, the structure of organization is essential to understand the possible scenarios: a compact organization is surely easier to manage by top

[6] *Never increase, beyond what is necessary, the number of entities required to explain anything, William of Ockham, Summa logicae* (1323)

managers, but there are some reasons that can force the clients to split out the execution phase between many smaller contractors. As often happen, there could be a gap between the company's Safety performance and the contractors' Safety performance; for example, in some cases, purchaser's reports underline that the companies occasionally working with contractors experienced unforeseen Safety problems.

Project can be complex, with limited time to complete works in which many contractors, with different background cultures, company cultures and attitude regarding OS&H issues were working together. The problems raised in such a scenario where connected to the internal interferences: to solve the situation managers must create a climate of communication and cooperation and, if necessary, use every tool, even if that means to totalize the surprising number of 994 meetings and round-tables. Project leaders must manage tasks and plans, but for Safety, behavioral issues were important: their own role in giving the good example and addressing OS&H issues is fundamental in creating a high-level Safety consciousness. Some purchasers want to raise standards of Safety not only for their own employees, but also for workers of the companies working for them. Improving the Safety performance of contractors has been one of the Occupational and Community S&H challenges and priorities, and a relevant part of their strategy.

f) Overview of best practices: Specific population:

It is always necessary to consider possible scenarios of high risk or deviations before to begin such great works. Particular attention must be focused on the problem of emergencies. Almost all the infrastructures analyzed, as already seen in previous points, have common characteristics: underground-works, many companies involved, interference problems, etc.. Practitioners designed detailed plans of emergency in which all bodies involved would intervene simultaneously and quickly. The most common tool used and suitable to ensure good results is a simulation movie: it is useful for outsiders to understand the entity of a possible accident, and for insiders, to better understand the procedures to follow in case of emergency.

In long tunnels, the access to the excavation face, where the presence of higher risk processes is supposed to be, depends from the distances to cover, the promptness of intervention and the available Safety equipment.

The procedures and the respect of specific regulations were at the basis of the emergency management, but in the perspective to reach an excellent effectiveness, interventions have to be immediately enforced. There are units working h 24 placed at the entrance of the yards, set up for emergency management: from equipped control-rooms, operators monitor and manage the site process and the Safety and Security facilities: control of site and tunnel access, switching on and off the ventilation, management of electrical and lighting systems, management of the traffic light system for the activation of escape routes. Meeting points and support organization for Fire and Security internal teams, Fire Fighters teams; Health Care people, etc. should moreover be available.

g) Dissemination of the Culture of Safety in a quality approach

Changes are, as in a continuous spiral, results of new knowledge and applied intelligence, and, at the same time, starting points and bases to develop new theories and applied researches, so that the result increases in theory can be directly transferred into practice.

The population not always welcomes Great Works, so managers must intervene to guarantee the Safety of workers and third parties even creating complex situations, as the uninterrupted presence of multiple police/army bodies, allocated at the yard to protect it from people contesting the infrastructure.

Despite the carefulness everybody put to comply with the Regulations, to ensure a high OS&H level it is necessary but not sufficient to strictly obey the laws: the whole system should be managed in a Quality approach. In complex cases, like those analyzed, the variables are so many that it is impossible to control everything without a systematic approach, essential to face the multiform and complex problems which can arise.

h) Not only information, formation and training, but promotion:

In every virtuous Management it becomes of pivotal importance to set ambitious goals to improve the previous situation. Taking such ambitious goals can be risky because nobody is sure to reach them, but it is an essential step, to see

tangible results: it helps in modifying machinery and equipment, and even in introducing small innovations that, if put all together into a symbolic chain, will substantially increase the global/overall quality level of the whole scenario.

Purchasers have a special role and responsibility as promoters of Good Practices on Safety.

In this optic, the coordination of many small and medium enterprises is of course more difficult, but in some cases purchasers decided to privilege the territorial wellbeing including local companies in the whole system. Furthermore, infrastructures have the chance not only to reach a ZERO impact, but also to have a positive environmental impact: positive benefits derive from the final outcome, and great works can lead to situations better than the starting ones, in particular thanks to their aesthetic characteristics. In some cases, managers introduced permanent facilities for inhabitants of the neighboring cities: the 24 h/d, 7/7 d/w open medical care should have been necessary in any case for the yards' workers, but is available also for the population. This decision was adopted since, in a perfect scenario of no work related accidents, it would have been always "useless" for the enterprise.

4.1.3 In closing

the above described examples highlight that lot can be done with tangible positive results, although a long way ahead remains, especially when we shift the focus from large yards to the small ones, where *paper-based Safety* is often the only available.

As stated in the previous chapter, and listed according to the 10 points, the dissemination of the Culture of Safety is a mean to prevent unwanted event.

The mutual exchange of information and experience on the improvement of OS&H between the Community of high experienced speakers and audience is a first step in such innovative experiences, thus all these works have been presented in an international Meeting.

It was an important opportunity of debate on the approaches and experiences on OS&H in relevant infrastructures, and confirmed the importance of the involvement of the general target and of figures with real decision-making power.

4.2. Highways

Highway maintenance yards are classified in the F – Construction[7] NACE sector, and the peculiarity introduces important OS&H criticalities. Therefore, lacks in Risk Assessment and Management produce a high number of work related accidents, as shown in the national and international accident databases. The Risks minimization requires both a through Risk Assessment and Management and an efficient Safety inspection activity. Such problems are particularly relevant in Italy, since a number of peculiar parameters makes the Italian highway system subject to frequent and important maintenance interventions often in complex scenarios. In this chapter are summarized the results of a systematic research work leading to an original approach to the Risk reduction, based both on innovative prevention solutions and on the optimization of the Safety inspection activities.

4.2.1 Italian Highways

The Italian Highway System covers more than 6000 km, with 1800 km of tunnels, bridges and viaducts, in continuous increase. This involves the necessity of systematic maintenance and special interventions, in a particularly relevant number of kilometres due to the highly variable Italian climatic conditions, imposing additional wear to structures and materials of large part of the highway net. Additional deterioration factors affect some highways stretches, among them mean altitude above sea level and traffic load.

7

F	Construction	F42.2.1	Construction of utility projects for fluids	F43.2.2	Plumbing, heat and air conditioning installation
F41	Construction of buildings	F42.2.2	Construction of utility projects for electricity and telecommunications	F43.2.9	Other construction installation
F41.1	Development of building projects	F42.9	Construction of other civil engineering projects	F43.3	Building completion and finishing
F41.1.0	Development of building projects	F42.9.1	Construction of water projects	F43.3.1	Plastering
F41.2	Construction of residential and non residential buildings	F42.9.9	Construction of other civil engineering projects n.e.c.	F43.3.2	Joinery installation
F41.2.0	Construction of residential and non residential buildings	F43	Specialised construction activities	F43.3.3	Floor and wall covering
F42	Civil engineering	F43.1	Demolition and site preparation	F43.3.4	Painting and glazing
F42.1	Construction of roads and railways	F43.1.1	Demolition	F43.3.9	Other building completion and finishing
F42.1.1	Construction of roads and motorways	F43.1.2	Site preparation	F43.9	Other specialised construction activities
F42.1.2	Construction of railways and underground railways	F43.1.3	Test drilling and boring	F43.9.1	Roofing activities
F42.1.3	Construction of bridges and tunnels	F43.2	Electrical, plumbing and other construction installation activities		
F42.2	Construction of utility projects	F43.2.1	Electrical installation		

Figure 25 - Italian Highway System

A large number of kilometers of Italian highways are located in mountain areas, where the atmospheric agents' action becomes relevant and causes additional stresses on structures and materials producing faster deterioration of such stretches.

Moreover, the predominance of freight transportation by motorways and the presence of crucial nodes of the network across the country, produce high and intense circulation of heavy vehicles on the involved branches, resulting in marked stress of pavement and structures.

To evaluate the traffic load on Italian highway system, Information were gathered from the Aiscat (Italian Authority Company for Highway and Tunnel Association) database. The Aiscat data show that in a large part of the Italian

highway net, hundreds of millions of vehicles per km circulate, most of which are heavy vehicles.

Table 12 - summarizes the "total" and "heavy vehicles" traffic rates (number of vehicles per km).

Cumulative data January-February 2015 (millions of vehicles per km)					
Italian highway stretches (companies)	**Total**	**Heavy vehicles**	**Italian highway stretches (companies)**	**Total**	**Heavy traffic**
Autostrade per l'Italia,	5928	1444.8	Centro Padane	135.1	46.6
Traforo Monte Bianco	1.54	0.5	Brescia-Padova	778.5	217.7
Traforo S.Bernardo	0.97	0.09	C.A.V.	234.9	60.8
R.A.V.	15.8		Brennero	617.6	177.3
S.I.T.A.F.	52	13.5	Autovie venete	331.3	105.7
S.A.V.	51.7	11.0	Autostrada dei fiori	154.2	39.4
A.TI.VA.	72.5	12.3	Aut.le della Cisa	83.9	25.6
Asti-Cuneo	18.5	4.5	S.A.L.T.	222.6	49.7
S.A.T.A.P. A 4	326.5	81.1	S.A.T.	24.1	5.3
S.A.T.A.P. A 21	267.6	92.3	Strada dei parchi	294.1	39.9
Torino-Savona	112.1	22.3	Tang.le di Napoli	140.9	11.7
Milano Serravalle- MI.Tang.li	202.3	41.0	Aut. Meridionali	223.8	20.7
Società di progetto BREBEMI	32.1	7.5	Consorzio Aut. Siciliane	210.5	32.7
Tang.le Esterna di Milano	3.2	0.7	Total	10536.3	2568.9

4.2.2 OS&H Data for highway maintenance activities

In the highway maintenance operations limited spaces, high power complex and peculiar machinery, haste to complete the work, and some misconduct of the users lead to a significant number of accidents, often characterized by dramatic Severity Rates. The multitude of work-related accident recorded in the Official Italian database of Inail -National Institute for Work Injury Insurance- confirms the high criticality of this kind of yards in terms of OS&H. The Inail database made possible the characterization of the most frequent causing deviations.

The following graphs summarize the data on events occurred in Italian highway maintenance yards during six years, from January 2008 until May 2013: information are codified according to the ESAW - European Statistics and Accidents at Work methodology, and consider the main characteristics of each event, the victim / employer, and the causes and circumstances. In the considered time span, on the Italian highway maintenance yards occurred 5562 non-fatal accidents and 87 fatal accidents (the 1.5% of the total). It is noteworthy that 86% of the fatal accidents are officially classified as "in itinere" (during trips to and from the yard) due to vehicle loss of control and causing neck, spine, neck vertebrae traumas, the remaining 14 % as bound with the specific yards activities. (Fig.22).

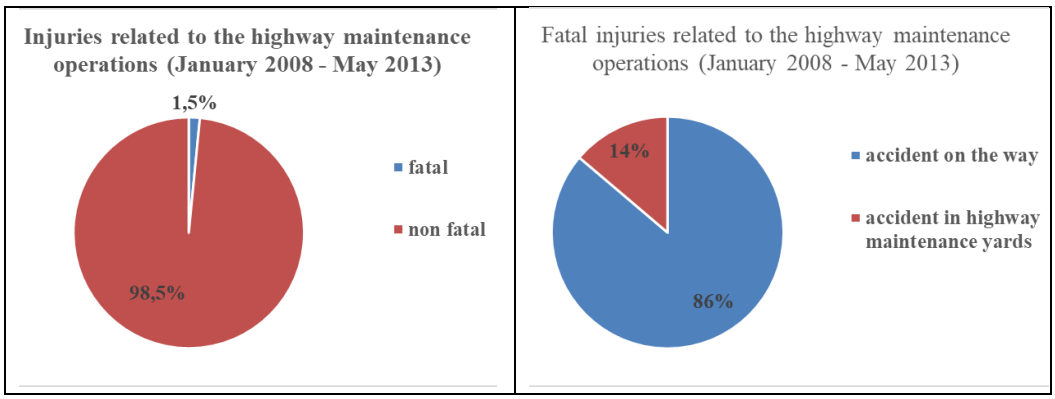


Figure 26 -(left) - consequences of work-related accidents involving highway maintenance operations;

Figure 26 summarizes the main causes and some details of non-fatal accidents in the highway maintenance yards. As shown in the left Figure 26, the 19% of non-fatal accidents occurred during highway maintenance operations are due to causes typical of similar temporary or mobile construction sites (slipping, tripping, materials and equipment, etc.), whilst the 55% are partly due to the special criticalities of highway yards (limited spaces, high power complex and peculiar machinery, etc.);

Figure 27, on the right, describes the seriousness of non-fatal injuries due to the special criticalities of highway yards

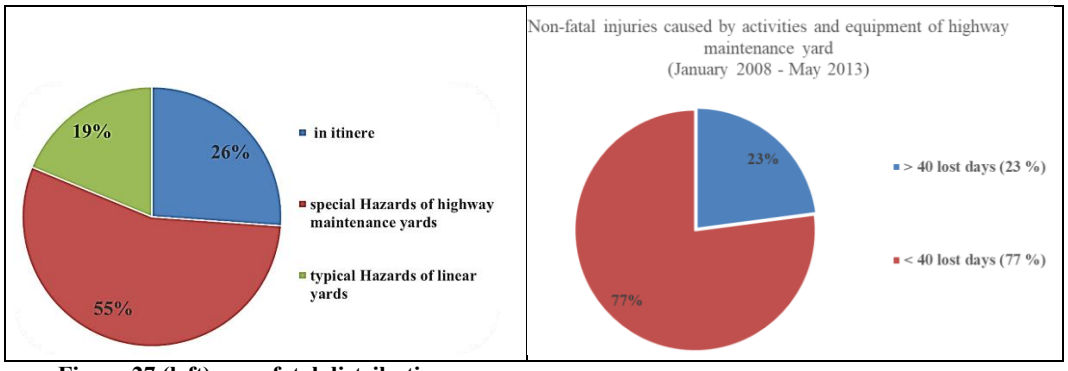


Figure 27 (left): non-fatal distribution;
Figure 27 (right): seriousness of non-fatal injuries

A comparison between Italian and USA data from 2003 to 2007 (*source OSHA*), confirmed the similarity in terms of hazard factors and criticalities of highway maintenance yards: limited spaces, high power complex and peculiar machinery, haste to complete the intervention, etc., even if the USA highway network and maintenance technologies are remarkably different.

According to the OSHA data, workers run over causes 50 % of the fatal accidents in the highway maintenance yards, and are ascribable to machines and

vehicles belonging directly to the construction firm that manages the site (54%), or to other companies involved in the work (46%).

The Inail database contains no information on the accidents caused by interference between traffic and maintenance sites (according to the OSHA database the run overs of maintenance workers due to traffic amounts to approximately 30% of the total).

Due to the importance of this aspect, investigating the National Statistical Institute (ISTAT) and Italian Automobile Association (ACI) data, to deepen the violations of the Traffic Laws, the result was impressive: the total number of sanctioned violations in 2013 amounted to more than 900.000 (560.000 due to excessive speed, 35.000 due in general to reckless driving). Even if no direct correlation is at present possible, countermeasures are certainly necessary.

4.2.3 RAM in Highway Maintenance Yards

An accurate knowledge and effective Risk Assessment in complex situations, among them the one under exam, requires a systematic approach, based on a rigorous schematizations of the various contexts, scenarios and types of maintenance and improvement yards, to bring into evidence the problems which may be added to those typical of a similar temporary or mobile construction sites.

Table 13, drawn for the more common yard typologies, and resulting from a throughout analysis of the Italian highway network, summarizes the main parameters which can directly or indirectly affect and condition the characteristics, the design and the Safety of both workers and third parties.

Table 13- highway maintenance yards classified on the basis of the main parameters which can affect their characteristics, design and Safety (in addition to those typical of a similar temporary or mobile construction sites)

PARAMETER	TYPICAL CRITICALITIES	EXAMPLE
type and characteristics of the yard	level of urgency, importance, extension, and duration of the activities	emergency repairs or activities which can be postponed and planned with no special haste, radical renovations and modifications;
	frequency of occurrence: exceptional / occasional / systematic	parts maintenance due to accidents, pavement repair/renovation, etc.;
	position and evolution in space: stationary / mobile yards	localized embankment maintenance, painting of lane markings;
	special yards	organized to make possible activities not directly related to the normal use of the highway;

"internal" parameters:	unique features of each situation	in case of emergency repairs, the seasonal conditions can require quite different design approaches even for the same activity
	available areas and special constraints, possible interference of contemporary activities	the limited areas usually available can be further reduced, e.g. by over bridges, and interference problems faced in presence of other yards, e.g. for the construction of a junction
	additional problems	poor Prevention through Design in terms of maintainability, typical of the less recent stretches. Equipment, materials and parts supplying, emergencies management, etc...
"external" parameters	orographic & geomorphological characteristics, mean weather conditions, traffic loads in general, and light / heavy traffic "seasonal" changes,..	different traffic loads, steeper stretches, straights and bend radii, windy conditions can introduce criticalities due to both the mean vehicle velocities, and the difference in speed between light and heavy vehicles, which modify both the importance and frequency of the maintenance interventions, and the risk of interference with the yard;
	special site characteristics, such as tunnels, viaducts, etc.	interventions in tunnels can require special ventilation and fittings, criticalities from old linings, etc..

Table 13 brings into clear evidence that every maintenance yard situation, if properly and thoroughly analyzed, presents unique features and Safety criticalities, and requires a special Prevention through Design approach for an effective Risk Management aimed to the elimination or minimization of the associated risks.

The proposed schematization, together with an in depth study and investigation of the intermediate and Root causes of the occurred accidents, can effectively support the Risk Management phase, and contribute to identify the most suitable design for each special situation. Even if nowadays the analysis of occurred accidents is limited to a general statistical approach, there are innovative investigation techniques available, of some help also in the discussion of the best control measures to interrupt the chain of causes of the event. Table 14 summarizes the results of the analysis of an accident, resulting from the use of the CCCP - (Computer-aided Cause Consequence for Prevention) technique (*Maida et al., 2015*).

Table 14 -- some possible Risk Management actions on the factors that can increase, in the case of highway maintenance yards, the Risk typical of similar temporary or mobile construction sites.

	factor	technical measure	other (organization & procedures)
Inter nal	ED	emergency solutions special for the context;	special emergency procedures;

	FC	due to the limited areas often available, throughout analysis of the risk of interference and introduction of physical/nonphysical Safety barriers;	introduction of strict work procedures; interruption of work in case of difficult environmental conditions (e.g. poor visibility);
	P	PtD approach special for the operation, including techniques, technologies and equipment selection, and organization definition;	special inspection and maintenance of machinery and fittings, special supervision and IFT;
	n	reduction to a minimum of the number of exposed workers, through a mechanization level as high as technically possible;	do;
External Risks	ED	collective protection systems (barriers, Truck Mounted Attenuators,…);	speed limits,
	FC	scheduling of the maintenance activities to minimize the need of interventions in critical traffic or weather conditions;	activities, shifts and trips to and from the yard organization;
	P	minimization of the number of maintenance interventions, through improved design choices and use of innovative materials and techniques;	Safety lanes, traffic detour, Speed limits, yard signage, etc.;
	n	as suggested for the internal risk management;	as suggested for the internal risk management.

4.2.4 Some results of the Research work

Two main topics may condition the Safety of both workers and third parties, in general and more so in the case of particularly risky and complex activities:

a) A widespread Culture of Safety among the designers, leads to the adoption of a PtD approach, which should consider both Safe Work Organization, and the Maximum Safety Technologically Achievable criteria, in coherence with the provisions of law. In fact, Italian Decree April 9, 2008, n. 81, and following amendments, derived from the 89/391 EEC Directive, where we can read: "Art.6. General Obligations on employers, c.2. The employer shall implement the measures referred to in the first subparagraph of paragraph 1 (necessary for the Safety and Health protection of workers, including prevention of occupational risks and provision of information and training, as well as provision of the necessary organization and means) on the basis of the following general principles of prevention: … (e) adapting to technical progress" (the 92/57/EEC Directive, also included in the Italian Decree April 9, 2008, n. 81, and following amendments,

reiterates and details these concepts, and sets this task to the 'Coordinator for Safety and Health matters at the project preparations stage').

These criteria should then be applied both to operations developed in the maintenance yard, and to the context in which the maintenance site is located.

Asides from the guidelines and good practices for the “normal” linear yard safety, and taken into account the contents of Table 13, some examples of technological improvements on the safety of the stretch and of the yard which already proved effective abroad are discussed.

b) The minimized Risk level achieved for the system should be preserved, and improved along the time, nowadays in accordance to quality principia. The aforementioned 92/57/EEC Directive sets this task to the ‘Coordinator for Safety and Health matters at the project execution stage’. Because of the number and complexity of the various different maintenance sites, the task of the Coordinator becomes very challenging, as he should deal with both the aspects that require high capacity of judgment, and those of mere routine.

following a phase of comprehension and study of the peculiarities in maintenance yards,an original and tested approach has been developed for Safety Analysis, periodic audits and inspections, aimed to optimize the work of the expert evaluator, and to increase the Safety of workers and third parties.

Table 15 - PtD &Quality Management

PtD approach

- Safe Work Organization and Maximum Safety Technologically Achievable (89/391 EEC Directive, enforced in Italy by D.Lgs.81/08)
- Coordinator for safety and health matters at the project preparations stage (92/57/EEC Directive)
- technological improvements on the safety

PtD approach → SAFETY OF BOTH WORKERS AND THIRD PARTIES ← **Quality Management**

Quality Management (e.g. according to ISO 45001)

- Preservation and improvement of the minimized Risk level achieved
- Coordinator for safety and health matters at the project execution stage (92/57/EEC Directive) → very challenging task
- original and well-tested approach to support the activity of the Coordinator for safety and health matters at the project execution stage

4.2.5 Examples of new technologies to support the Safety of highway and of the maintenance yard workers

In this scenario, side by side the technical and practical aspects, the Research becomes of pivotal importance to ensure an improvement in the Culture of Safety at all levels of the system and to implement Preventive actions in two different ways.

To better understand this phenomenon, it is necessary to refresh what has been discussed in the 2nd chapter, talking again about the change of conception of Safety, "from *Safety I as the non-occurrence of an unwanted event*, to *Safety II* as *the ability to succeed under expected and unexpected conditions alike"*.

Indeed, there will be a direct Prevention, introducing new technologies and testing new procedures to *directly* avoid unwanted events, or *indirect* actions, improving -for example- materials quality, reducing the need of maintenance interventions, to reduce the time of exposure of workers and indirectly have a safer situation.

The improvement of the Risk Management necessarily involves the enhancement of effectiveness of the prevention/protection measurements and of the accuracy in the Safety inspections. The possible selection, in particular engineered databases, of the most suitable innovative solution for prevention, for each specific categorized context, makes higher the effectiveness of each measurement. The "visual" Safety trend, both of the whole yard and of the single matter, becomes a useful instrument to achieve and improve the requirements of the OS&H regulations, giving also beneficial indications for the deepened supervision of activities characterized by intrinsic hidden criticalities.

4.2.6 Technical improvements for the management of possible distributed traffic ⇆ yard interferences

In case of mobile linear yards, the usual segregation of the working areas from the traffic, based on Jersey barriers, involves that the progressive modification of the yard area makes necessary a similar modification of the barriers layout.

The traditional procedure (Figure 28) implies that the yard workers manually unfasten each module of the barrier, lift it up and move it to the new position by means of a crane; finally, it is necessary to reconnect the module to the already

moved barrier. Workers and equipment (truck and crane) operate in immediate proximity of the regular traffic; as sole Safety means, signs, flagman and light signals are introduced to draw the attention of the highway users.

Hence this operation is one of the most critical in the highway maintenance yards Safety.

The adoption of the mechanized Barrier Zipper System (BZS), technique for Jersey barrier transfer makes possible a significant Risk Reduction for both workers and users, see Fig. 25, and Tab 11 summarizing the results of a PHA (Preliminary Hazard Analysis) applied to the traditional and BSZ Jersey barrier transfer techniques.

Figure 28 – barrier transfer: traditional procedure

;

Figure 29 - mechanized "Barrier Zipper" technique.

Table 16 - Extract of a Preliminary Hazard Analysis on barrier movement activity

Hazard	Cause (1)	Risk reduction achieved with the "Barrier Zipper" technique	Note
workers and flagmen run over by vehicles unrelated to the yard	regular traffic in proximity of the working areas	number and exposure of workers to run over by vehicles unrelated to the yard substantially reduced	during the barrier tranfer with the "Barrier Zipper" technique, no workers operate in unprotected areas
yard equipment struck by vehicles unrelated to the yard	unprotected yard vehicles during the barrier tranfer	minimization of unprotected yard vehicles	the Barrier Transfer Machine is the sole machine necessary, and operates safeguarded by the barrier already tranferred

crushing	handling of heavy loads	highly mechanized activity carried out from cabin and safe areas	the "Barrier Zipper" technique does not imply manual operations such as unfastening/fastening of each module
……	……	……	……

(1) some parameters typical of the Italian highway scenarios, can further increase the Risk for both yard workers and users.

The Risk reduction possible through the adoption of the described "Barrier Zipper" solution results (see Figure 29 right and Table 16) from:

- ✓ the reduction of P, thanks to the continuous barrier covering the whole length of the yard. The Safety of drivers is also increased, thanks to the clarity of the situation;
- ✓ the reduction of F, since the yard workers operate exclusively from the safe side of the barrier;
- ✓ the reduction of n, thanks to the mechanization of the system.

4.2.7 Technical improvements for the management of possible localized traffic ⇆ yard interferences

In case of stationary maintenance yards of limited extension and duration where no Jersey barriers are present, the protection of the yard from the hazard of vehicles irruption is possible by the positioning of obstacles of adequate size and mass (usually some heavy machineries or trucks). Obviously, such an improvised approach, even if somehow effective to the purpose, can dramatically worsen the seriousness of the consequences for the driver of the impacting vehicle.

Some Truck Mounted Attenuator (TMA) devices are presently available, specially designed to improve the yard protection and reduce the collateral damages. Figure 30 shows the basic idea: to increase progressively the resistance to the impacting vehicle momentum, and to handle as well as possible the direction of impact, preventing rebounds or uncontrolled deviations.

Figure 30 - Truck mounted attenuator. and crash test results

Granted that, in this case also, the discussed measures signaling the yard are necessary, the Risk reduction possible through the adoption of the described solution results from the reduction of the exposure to the Hazard, since the possibility of irruption of vehicles out of control into the working area is limited; asides, the Safety of drivers is improved

4.2.8 Innovative materials and laying technologies for the highway pavement, which can improve the stretch Safety, and directly reduce the need for maintenance interventions

As shown by the Cost errors diagram, the most relevant impact in terms of Safety is made in the first design phases of a project. A tangible example in the Highway system is the growing number of innovative materials and laying technologies for the pavements and, thanks to the applied research, innovative bituminous binders, aggregates, additives and related products. The main targets are technical and economic efficiency, pavement duration even in heavy use conditions, and environmental issues.

Fiber or steel-net reinforced pavements, flexible and high resistance pavements in Polymermodified Binders, and other solutions can in some cases already provide important benefits in terms of resistance to stresses induced by heavy vehicles, cracking and cracks propagation, together with excellent surface characteristics, improved adherence, reduced aquaplaning or splash & spray phenomena and degradation by deicing, and good soundproofing.

It is important the awareness of decision makers to consider the Safety from the firs steps, in fact the use of such materials and technologies for new highway stretches, or to replace the currently existing ones, can enhance the system availability, and then directly reduce the number of necessary repair/renovation interventions, i.e. the need of maintenance yards. Hence, the FC value decreases, thanks to the increase of M.T.B.F. (Mean Time Between failures), the latter being

the results of the sum of M.T.T.F. (Mean Time To Failure) + M.T.T.R. (Mean Time To Repair).

Obviously, a preliminary risk analysis is essential, to define the expectable M.T.T.R. value, and make sure not to have introduced new hazard factors for the maintenance yard workers.

4.2.9 Original approach to system organization, proposed to support the activity of the 'Coordinator for Safety and Health matters at the project execution stage'

According to the aforementioned EEC Directives, the minimized Risk level achieved for the system should be preserved, and improved along the time.

In particular, the 'Coordinator for Safety and Health matters at the project execution stage' is charged of the tasks listed below (92/57/EEC Directive, Article 6), the main reference for his activity consisting in verifying the correct implementation of the Safety and Health Plan (drawn by the 'Coordinator for Safety and Health matters at the project preparations stage').

> ***Project execution stage: duties of coordinators***
>
> *The coordinator(s) for Safety and Health matters during the project execution stage appointed in accordance with Article 3 (1) shall:*
>
> *(a) coordinate implementation of the general principles of prevention and Safety:*
>
> *- when technical and/or organizational aspects are being decided, in order to plan the various items or stages of work which are to take place simultaneously or in succession,*
>
> *- when estimating the period required for completing such work or work stages;*
>
> *(b) coordinate implementation of the relevant provisions in order to ensure that employers and, if necessary for the protection of workers, self-employed persons:*
>
> *- apply the principles referred to in Article 8 in a consistent manner,*
>
> *- where required, follow the Safety and Health plan referred to in Article 5 (b);*
>
> *(c) make, or cause to be made, any adjustments required to the Safety and Health plan referred to in Article 5 (b) and the file referred to in Article 5 (c) to take account of the progress of the work and any changes which have occurred;*

(d) organize cooperation between employers, including successive employers on the same site, coordination of their activities with a view to protecting workers and preventing accidents and occupational Health hazards and reciprocal information as provided for in Article 6 (4) of Directive 89/391/EEC, ensuring that self-employed persons are brought into this process where necessary;

(e) coordinate arrangements to check that the working procedures are being implemented correclty;

(f) take the steps necessary to ensure that only authorized person are allowed onto the construction site.

Taken into account the typical situation of a large number of construction activities, the 'Coordinator for Safety and Health matters at the project execution stage' should devote special care in the supervision of the 3rd phase, Risk Management.

In particular, he should evaluate the Safety documentation drawn under the employer's responsibility and, if necessary, ask for amendments, the Safety Documentation drawn by the employers (whose the responsibility remains in any case unaffected, as provided for in Directive 89/391/EEC).

This also is somehow frustrating, since, as shown in Figure 31, only in a limited number of cases the situation results directly acceptable.

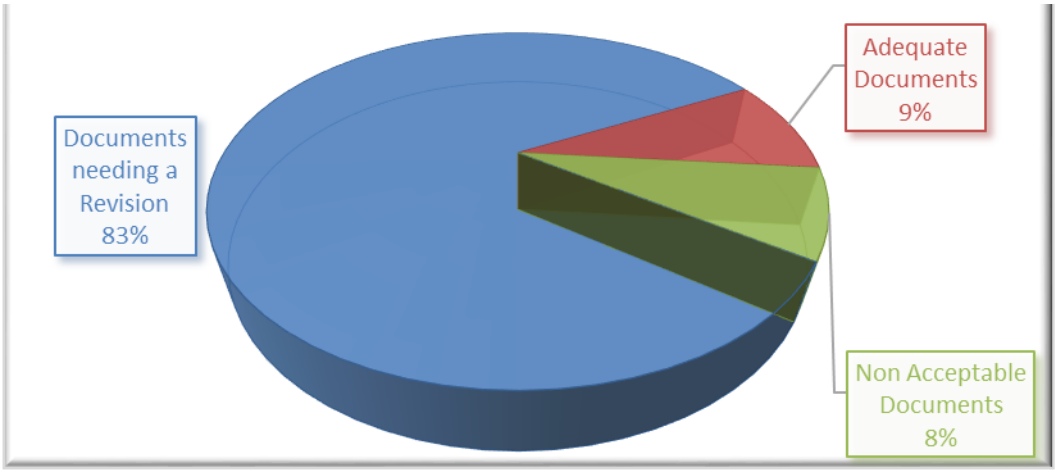


Figure 31 - Results from a statistical analysis on the congruence between the Safety and Health Plan and the Safety Documentation drawn by the employers, in a number of real cases

The 'Coordinator for Safety and Health matters at the project execution stage' supervises the activities at the yard, an essential step to guarantee real OS&H, it is usually possible to make a distinction between:

- ✓ an in depth level SUPERVISION, involving an accurate and critical appraisal of the general yard layout and organization, Safety solutions for normal operating conditions and emergency situations, cooperation between employers if necessary, machinery selection and their Safety characteristics included, crew composition and adequacy, etc. essential to investigate and control the hidden criticalities, if any;
- ✓ an elementary level SUPERVISION, aimed to verify the evidences in terms of compliance of the site, machinery and fittings characteristics, and workers behavior with the dictates of the law, and the specifications of the Safety and Health Plan. Apart their intrinsic importance, the evident criticalities should be considered symptomatic of not immediately identifiable OS&H problems.

For the optimization of supervision / inspection activities, a new tool was developed, based on the appropriate use of Fellow Supervisors to support the Coordinator in the routine activities, with the added benefit of an increased presence of "Safety people" at the yard. The setup of an appropriate data gathering, recording and mining system, organized in interlinked cards in logical sequence, contributes to the efficiency and thoroughness of the work of the both the Coordinator and the Fellow Supervisors. The results of tests on a real case –input data provided by the Prosecutor Office, which proposed the study, is significant.

Because of the number and complexity of the various different highway maintenance sites, the task of the Coordinator becomes very challenging, as he should deal with both the required aspects both high expertise and /competent judgment, and those of mere routine.

In fact, practical experiences confirm that the elementary level inspections must be frequent, to promote the attention to OS&H of qualified personnel working in the yard, while in depth inspections can be sparser, but thoroughly cover the critical operations.

Therefore, an effective approach to the possible criticalities entails a widespread Culture of Safety, but different levels of expertise:

a) highly qualified, to perceive and manage problems of difficult identification, involving accurate and critical appraisal of the general yard layout and organization, Safety solutions for normal conditions and emergencies, cooperation between

employers if necessary, equipment selection and its Safety characteristics, crew composition and adequacy, etc.;

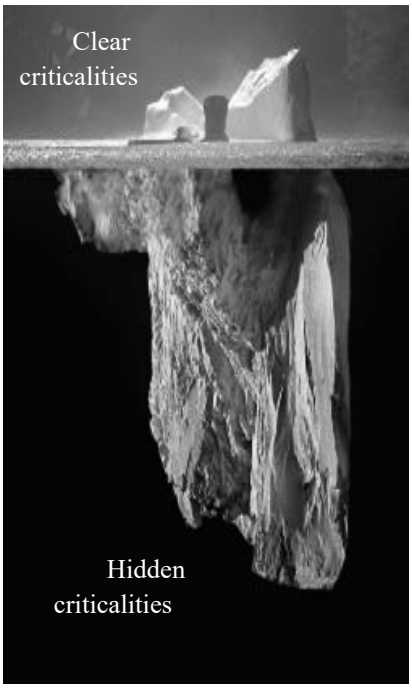
b) elementary knowledge of the more patent lacks in organization, actual crew composition and adequacy, equipment faults or misuse, and workers misconduct.

The approach focuses on the optimization of the work of the 'Coordinator for Safety and Health matters at the project execution stage' (from here 'Expert Evaluator'), and of his staff (from here 'Fellow Evaluators'), and covers the Safety analysis and the periodic audits and inspections phases.

The expert evaluator carries out personally the in-depth preliminary analysis, and the on-site inspections when necessary, and organizes, coordinates and discusses the activities of Fellow evaluators, who access the yard frequently as shown in Table 17.

Table 17 - tasks and typology of evaluator

Fellow evaluator
✓ *verifies the bureaucratic aspects of contractual regularity and Safety;* ✓ *can tell and annotates the clear non-conformities to the OS&H regulations and good practices.*
Expert evaluator (CSE)
✓ *examines and verifies the congruence between the Safety and Health Plan and the Safety Documentation drawn by the employers;* ✓ *makes, or causes to be made, any adjustments required to the Safety and Health Plan;* ✓ *supervises to activities particularly critical for OS&H.* ✓ makes available -to support the work of the Fellow evaluators- adequate data collection forms, and evaluation indexes for weighing situations and behaviors complying/not complying with the basic the OS&H regulations and good practices.



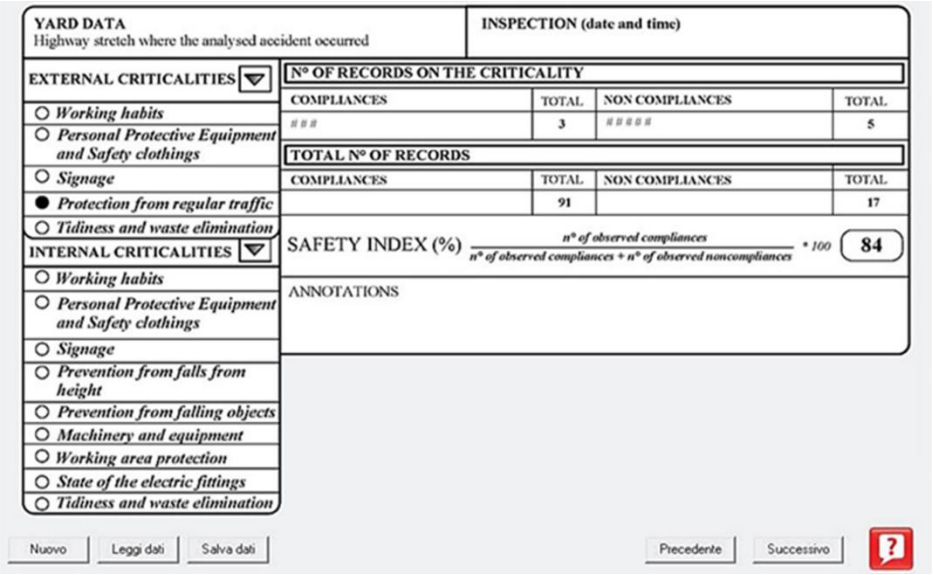


Figure 32 - example of Safety Index Datasheet, completed by a Fellow evaluator (filled in for example)

The Safety Index adopted is an evolution of what suggested by Laitinen (*Laitinen. et al, 1998, 2002, 2006*) and is expressed as follow:

$$Safety\ Index = \frac{\#\ observed\ compliances}{\#\ observed\ compliances\ +\ \#\ observed\ NON\ compliances} * 100$$

The Safety Index can be directly calculated as a weighted average of the results of all the observations made in the yard in relation to the different deviation scenarios under observation, or, as we also tested, subject to corrective coefficients ascribed to the various deviation scenarios, as a function of the statistical frequency and / or the severity of the consequences.

- ✓ completes the evaluation of all the gathered information, so that an exhaustive and structured rating on the OS&H of the yard remains to acts, helping the user - if necessary - and providing indications both on any measures to be taken against the employers, and on possible improvements of OS&H (Figure 33).

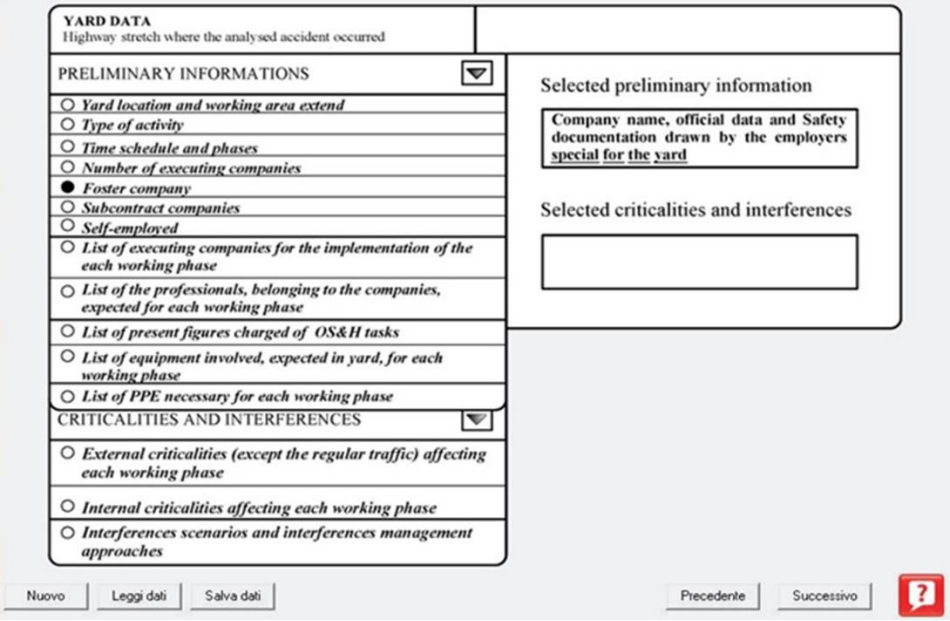


Figure 33 - Compendium sheet completed by the expert evaluator, containing his direct observations, and the results of the activities of the Fellow evaluators

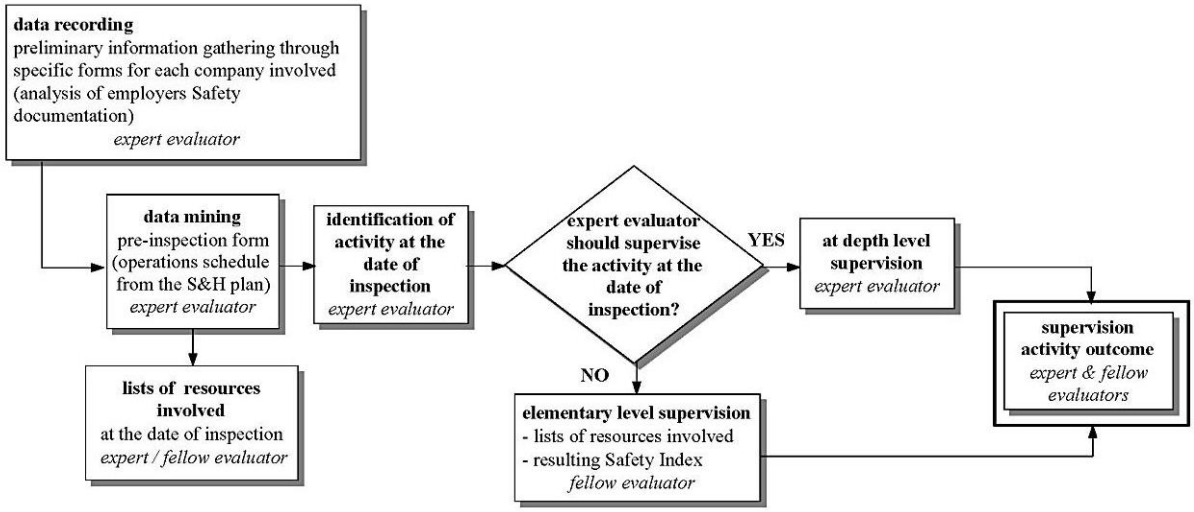


Figure 34 - summarizes the logical framework of the approach. A side benefit of the proposed approach is the possibility to implement the data collection forms in a computer assisted system, a software in Visual Basic

The approach can be of some help also for the National Inspectorate supervisors and their staff.

Thanks to a special organization of the Safety data management system, based on forms for the systematic and thorough recording of the results of the evaluation and inspection activities, and to the introduction of Safety Indexes, the technique can lead to a formalized, rigorous and objective rating on the OS&H yard situation. The approach results precious for an effective and timely identification of both clear

and embedded Safety criticalities for workers and third parties, and for the adoption of possible improvements of OS&H.

The suggested approach represents then an efficacious tool for:

- ✓ successful inspections of OS&H at highway maintenance yards;
- ✓ improving the general yard OS&H conditions;
- ✓ widespread dissemination of the Culture of Safety at all levels, Fellow evaluators included;
- ✓ the OS&H management in a sound quality approach.

Thanks to its simple structure, and to the interlinked logical sequence, the proposed approach can be supported by Computer Assisted techniques. A test-software-release proved to be of some help for the completeness of the data and observation sheets, the calculation of the Safety Index, and for the creation of OS&H database for each maintenance yard, and for several yard typologies as previously classified.

4.2.10 In closing

The peculiarity of the highway maintenance yards requires a careful Risk Assessment and Management, and efficient Safety inspection activity, particularly relevant in the case of Italian scenarios, where characteristics could produce an increase of the Risks.

The application of the approach to support the Safety inspection could highlight the importance of Safety inspections as prevention instrument, more than as penalty mean, assuming an important role in spreading the Culture of Safety. The clear non-conformities trend, achieved by the systematic implementation of the method in the internal Safety inspections, permits, to the executing companies, not only to raise awareness on the possible Safety lacks, but also improvement incentive. The executing companies, through the clear criticalities identification, independently could fix unsafe situations, which, otherwise, during external Safety inspections accomplished by the Safety and Health Officers, should be subject to sanctions. Moreover, interventions focused to minimize the clear criticalities act indirectly on lacking OS&H situations that conceal severe criticalities.

The implementation of the method, also, allows, to the workers, to better know all the dangerous activities and behaviors, advised in the Safety and Health laws

and to become aware for their Safety and Health since in violation of the Safety and Health regulations. Therefore, the workers raise awareness that the compliance of the Safety and Health laws OS&H regulations essentially aims to protect their Safety and Health

Finally, the frequent and long-lasting systematic presence of Fellow Evaluators at the yard can contribute to a substantial improvement, in terms of increased attention to OS&H problems and responsibilities, continuous cooperation on the Safety aspects, and in more general terms wide spreading of the Culture of Safety. Even if in situ tests of the suggested approach and the engineering of the software are still undergoing enhancement, the improvement of the general attention to the OS&H issues, in some highway maintenance yards, as recorded by experts of the National Inspectorate supervisors, appear encouraging.

4.3. Arts, Entertainment and Recreation

The following session will describe other jobs presenting several issues: in general, in the bigger NACE sectors the occurrence of unwanted events is known thanks to the statistical inference done during the past due to the numerous cases analyzed. This operation is impossible when analysts want to know other smaller sectors or, as in the following pages, a sub category of a wider sector. In the case of stage collapses, the categorization in the NACE, could result in R. Arts, Entertainment and Recreation, or in F., Construction. In both cases it results hard to find literature or statistics because of the (luckily) small number of unwanted events. The study started from three Italian accidents that made the interest of the Parliament rise and brought to the promulgation of a dedicated Regulation. To know in depth this phenomenon, the research started from a strict data mining. In this case, official databases were completely useless, there was a blog presenting a list of accidents but not in a standardized description and without reference to the source. Thus, to draw a description of the current situation in this field, the only option was a research in internet, with a cross control of websites – more or less-updated and a subsequent collection of all the events occurred.

4.3.1 The Stage collapses situation.

The fatalities occurred between 2011 and 2013 in the field of Arts, Entertainment and Recreation persuaded the legislator to intervene by specific provisions to ensure the Safety and Health of the workers involved.

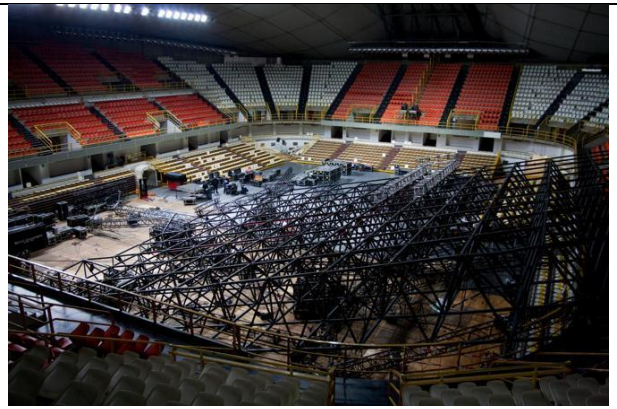
The legislator wanted to apply the principle of the specialty of the standard (article 298 of Legislative Decree 81/2008), which states that in case of similar areas, a fact must be referred to the specific Provision instead of the general one.

In this context, in fact, the “stage activities” are classified as specific ones, which are similar to those carried out in the shipbuilding sector, but at the same time distinguished by it. This distinction must be understood as more similar to those typical of general construction works to other activities involving work at height, in which "Entertainment activities" are certainly included.

However, a substantial difference is that scaffolding - or temporary works in general, are artifacts temporarily used for the period necessary for the execution of works (eg building walls, formwork, etc.), but they are not, as the stages, never functional to themselves.

The event analyzed and resumed in the Table 18, presents the above mentioned: an approximate investigation, pointed out criticalities linked to the general activity of Construction, but an in depth analysis, highlighted all the peculiarity of this NACE activity.

Table 18 - case history investigation results

<table>
<tr><td colspan="2">Accident Stage collapse # https://www.repubblica.it/cronaca/2012/03/05/news/crollo_palco_pausini_reggio_calabria-30961261/</td></tr>
<tr><td>ACTIVITY SECTOR: Theatrical Services (US 7922) USA// R90.0.2
Support activities to performing arts (NACE)</td><td>NOTES: the structure collapsed around 2 am, while workers were settling everything for the concert of the following day.</td></tr>
<tr><td rowspan="2">  </td><td>CONSEQUENCE → 1 fatality : crushed by the collapsed stage
2 wounded: struck by falling stage</td></tr>
<tr><td>Description:
Victim was 32 years old, from Rome, expert worker for a Service Company serving a multitude of artists all around Italy.
Employee#1 was at the bottom of the stage, waiting for his turn to start working. A truss fell crushing workers.
Employees#2 &#3 were hit by the falling stage parts and have been suddenly hospitalized.
It was one of three stages available, the medium one (it fills 15 trucks) already used and that has not ever given any issue. […]. If it collapsed during the concert, it would have been a tragedy.</td></tr>
<tr><td colspan="2">The identification of the client, to address the responsibility. Often exists a coexistence of different commissions - artistic production, local production and agencies - which divide ownership, power, and decision-making power. In the Decree, instead, they have to be the prerogative of a single subject,. This position is also confirmed in the investigation where the pursued were seven, on charges of homicide, including the representative of the F & P Group, commissioner of the works, the design engineer, the owner of the company that provided the stage Italstage, a member of the Municipality of Reggio, the coordinator of Safety for the execution stage of the works and the owner of the event - the representative by Esse Emme Musica.(5 of them convicted)</td></tr>
</table>

Analyzing the fact, the time of occurrence could be an indicator of the absence of defined working hours: having a strict schedule in which workers have to disassemble, travel and re building the stage between two shows, so that they do not have a lot of time off, and they have to work overnight to be ready on time. The victim was an expert rigger, informed and trained to do his job and even his colleagues, were not able to explain

what it could have happened to make the stage collapse. An unexpected aspect emerged during the investigation, was the difficulty to address the duties and the responsibilities due to the presence of several companies and the absence of a clear regulation.

The 9 August 2014 was enforced the Interministerial Decree of 22 July 2014 ("Stages Decree"), which states that “the provisions of Title IV of Legislative Decree 81/2008, in order to ensure Health and Safety of workers, cover the phases of assembly and dismantling temporary works, including their set-up and dismantling with audio, lights and stage systems, realized for musical, cinematographic, theatrical and entertainment shows”.

A widespread Culture of Safety in sectors like the *Entertainment activity* one resulted to be essential, in particular for the lack of regulations and the complexity of the scenario in such a short time-lapse. The new decree introduced important changes to the general regulation to simplify procedures, address responsibilities and solve the previous lacks. In Table 19 there is a confrontation of the differences.

Table 19 - comparison of general Italian Regulation Legislative Decree 81/2008 and specific Regulation about Stages, Interministerial Decree 22 July 2014

D.Lgs. 81/2008	**Peculiarity of *Stage Decree***
The client (or project manager) adheres to the general principles and measures of protection, when making architectural, technical and organizational choices, in order to plan the several activities or work phases that will take place simultaneously or subsequently.	The responsible acquires the following minimum information on the site where the temporary work is installed: - dimensions of the site, of the temporary work also in relation to the safe handling of the elements constituting the stage and the related equipment: - maximum admissible load of the ground in relation to the stresses induced by the work. - maximum admissible load of any existing structures or anchor points to be used for lifting trusses or other equipment; - presence of interfering artifacts; - electrical Safety.
The client (or the project manager) verifies the technical and professional suitability of the contractors, contractors and self-employed workers.	The verification is carried out by acquiring the certificate of registration with the *Camera di commercio, industria e artigianato* and the DURC, accompanied by a self-certification regarding the possession of the other requirements provided for by Legislative Decree 81/2008 (Annex XVII). In the case of foreign contracting companies, the verification can be demonstrated through a specific form (Annex II D.I. 22 July 2014).
The Safety Document has to comply the minimum contents of the D.Lgs. 81/2008 (Aneex XV).	**The Safety Document** has to comply the minimum contents of the D.I. 22 July 2014 (Annex III).

D.Lgs. 81/2008	Peculiarity of *Stage Decree*
The coordinator for Safety and Health matters at the Project stage has to draw up a Safety Document.	Not necessary.

Thus, it became of pivotal importance the definition of activities included in the field of application of the new decree.

The data mining highlights a substantial lack of events in the official databases, due to the difficulty of classification of the injured people (as workers or public) or to the classification in the NACE sectors (Construction, Arts and Entertainments, Others,..).

The result is that, to have an idea of the worldwide scenario of this phenomenon, the research has been conducted on less influential sources (newspapers, blogs, journals,..) as already said, completing it with a cross control of websites.

The sketch is a widespread underestimated phenomenon, never analyzed or systematically assessed in order to identify root causes, deviations and possible consequences (even Worst Credible Case) in such a kind of scenarios. Apparently, the number of events presented is not representative at all, as discussed in Manuele, the sample should be representative and it cannot be simplified as the Heinrich model 300 – 29 – 1. Thus, having these case histories, analysts could only use them to notice possible scenarios and list direct and root causes to avoid them in future, identify hazards, workers or third parties exposed, contact factors of people involved, but none statistical inference about probability of occurrence resulted possible.

In Table 20 the case histories have been summarized and standardized, identifying common parameters useful to understand the criticalities linked to the “Entertainment Activities”.

Table 20 - accidents related to Entertainment activities

day	where	capacity	event	fatalities	injured	time	description	source
1. 13/08/1990.	Windgate Field in Brooklyn, N.Y.		Curtis Mayfield	x	1 – tetraplegic	during the concert	a gust of wind from a fast-moving storm sent a lighting rig tumbling down onto him, // lighting rig at an outdoor New York show fell and struck him breaking his neck and paralyzing him from the neck down.	New York Times
2. 15/06/2007	Parco San Giuliano a Venezia Mestre	40.000	'Heineken Jammin' Festival	x	official data 30 injured (broken legs and head traumas)	during the concert	Gusts of wind and hailstorm hit the 6 towers holding lights and speakers until they collapsed.	Repubblica
3. 16/07/2009	Stadio Vélodrome di Marsiglia	60.000	Madonna	2	9 injured	17.15.same day	Four craves were positioning the roof of the stage, but it suddenly overbalanced, making a crave fall down on the structure of tangled web of steel, aluminum, and stretched cables.	Repubblica Le figaro
4. 1/08/2009.	Camrose, Alberta canada	with daily averages 25.000 /four-days event	Big Valley Jamboree country music festival	1	75 people had been treated for injuries	during the concert	Wind gusts of 100 kilometers per hour, concert staff had started evacuating the stage, but it was too late, the stage to collapse and heavy speakers crushed the victim.	Globalnews CBC
5. 04/07/2010	Parco San Giuliano a Venezia Mestre	24.561 day before	Heineken jamming festival	x	3 injured, 17 guys in hypothermia	20.00 during the concert	rain strom	la Stampa wikipedia

6. 18/07/2011	Ottawa River Parkway	300.000 attendees each year/12-days	Cisco Ottawa Bluesfest	x	According to a CTV report, Ottawa paramedics 1 was with life-threatening injuries Another "severe injuries."	7:20 p.m on the last night of festival	Thunderstorms with wind gusts up to 96 km/h began around 7:30 p.m. and continued on and off through the evening. Wind gusts of up to 117 km/h	CBC
7. 7/08/2011	Brady Block Party, Tulsa oklaoma	almost 10.000.	Flaming Lips'	x	Nobody was hurt in the accident	during the concert	the sun abruptly gave way to rain torrents, and winds pummeled the stage at 110 to 130 kilometers per hour the band's 4,5 meters video screen toppled over the back of the stage, prompting gasps from the audience and pushing Ivins to leap out of the way to avoid a catastrophic injury	Rollingstone
8. 13/08/2011	Indiana State Fair	12.000	Sugarland	7	58	8:46 p.m. during the concert	Inadequate capacity of lateral load resisting system and a wind gust from a severe thunderstorm. winds over 97 km per hour were expected **<< OSHA-DOL >>**	wikipedia CNN OSHA-DOL
9. 19/08/2011	It is held within a large enclosure of fields and woodland	60.000	Pukkelpop music festival	5	140 people were injured in the storm, 10 of them seriously	during the concert	Staging collapsed, giant screens fell, tents were flattened and trees were uprooted, all in the space of minutes after the storm struck	washingtonpost bbc
10. 12 /12/2011	Palatrieste - Trieste	6.943 seats	Jovanotti	1	12 injured – expert workers	14.	The 'ground support' holding lights and speakers, collapsed	ansa
11. 02/03/2012	Stockholm' s Globe Arena	16.000 seats	Avicii	x	6 injured, 1 serious condition	during the concert	Enthusiastic crowd jumping up and down in sync to the beat of the music, which can create tremendous live loading on a structure 30 people "plummetted four metres to the ground	Hollywood reporter youtube

12. 18/04/2012	Mount Herzl Jerusalem, Israel		National Fallen Soldiers and Victims of Terrorism Remembrance Day ceremony	1	7	during the concert	it was very windy at the time of the collapse, and a truss laden with lights fell when a cable failed to stabilize the structure. The structure was about 10 meters tall. An initial investigation revealed that a cable supporting the lighting fixture truss was torn apart and as a result, the fixtures collapsed and dragged a concrete cube that weighs a few tons.	the times of Israel
13. 16/06/2012	Downsview Park, Toronto	sold out	Radiohead	1	3 severe injured	1 hour before the opening	A video monitor weighing 2.270 kilograms fell, killing instantly the victim.	wikipwdia cbc the guardian
14. 19/06/2013	Forum di Assago, Milan	12.700	Kiss	1	1	2.46 am – after the end of the concert	three workers were disassembling the stage working on a goods lift, when a steel cable broke making them fall for 15 meters	corriere
15. 10/08/2013	Cleveland County Fairgrounds near Shelby, North Carolina	810 people.	The After	x	no one got hurt	3:30 p.m at the end of the sound check	wind gust from an approaching storm blew the overhead lighting and canopy support trusses over.	theatre Safety blog
16. 29/10/2015	Guangxi Stadium, Nanning, China	60.000	Jolin Tsai	1	13 injured	5PM, show scheduled Saturday (Oct 31)	the ground supported stage truss system collapsed. Deconstructing a tangled web of steel, aluminum, and stretched cables is a dangerous endeavor - stress in materials can create booby-traps due to spring loading and fractures in components that have not yet fully failed	xinhuanet
17. 20/05/2017	Bari (street) ITALY		Pane e Pomodoro festival	x	1	20:30 – before the opening	A steel part of the stage was in a tornado and hit the victim's head, promptly treated by the ambulance and resulting with a no severe prognosis	video.repubblica

18. 30/09/2017	Manhattan Center Hammerstein Ballroom di New York	2.200	Marilyn Manson	x	1 - plate and 10 screws in his fibula	almost the end of the concert	During New York concert, a support collapsed and stage scenery fell striking the singer	youtube bbc
19. 17/12/2017	Esteio, a Porto Alegre, in Brasile	over 5.000	Atmosphere Festival - dj Kaleb Freitas	1 - dj	x	during the concert	Unexpected gusts of wind and hailstorm hit the stage that collapsing struck the performer (dj)	the journal

Of all these cases, just one occurred in the United States has been reported in the official database of the OSHA-DOL.

Table 21 - Inspection detail (a)

Inspection: 315637181 - I.A.T.S.E. Local 30

Inspection Information - Office: Indiana

Nr: 315637181	Report ID: 0551800	Open Date: 08/17/2011		
I.A.T.S.E. Local 30 1407 East Riverside Drive Indianapolis, IN 46204		Union Status: Union		
SIC: 7922/Theatrical Producers (Except Motion Picture) and Miscellaneous Theatrical Services				
NAICS: 561310/Employment Placement Agencies				
Inspection Type:	Accident			
Scope:	Partial	Advanced Notice:	N	
Ownership:	Private			
Safety/Health:	Safety	Close Conference:	01/26/2012	
Planning Guide:	Safety-Manufacturing	Close Case:	09/23/2013	
Related Activity:	Type Accident	ID 100993740	Safety	Health

Violation Summary

	Serious	Willful	Repeat	Other	Unclass	Total
Initial Violations	4					4
Current Violations						
Initial Penalty	$10,500	$0	$0	$0	$0	$10,500
Current Penalty	$0	$0	$0	$0	$0	$0
FTA Amount	$0	$0	$0	$0	$0	$0

Violation Items

	#	ID	Type	Standard	Issuance	Abate	Curr$	Init$	Fta$	Contest	LastEvent
Deleted	1.	01001	Serious	2200080101	02/08/2012	03/06/2012	$3,500	$3,500	$0	02/29/2012	J - ALJ Decision
Deleted	2.	01002	Serious	19100132 A	02/02/2012	03/20/2012	$3,500	$3,500	$0	02/29/2012	J - ALJ Decision
Deleted	3.	01003	Serious	19100132 D02	02/08/2012	03/26/2012	$3,500	$3,500	$0	02/29/2012	J - ALJ Decision
Deleted	4.	02001	Serious	19040001 A02	02/08/2012	03/26/2012	$1,000	$0	$0	02/29/2012	J - ALJ Decision

Accident Investigation Summary

Summary Nr: 200999407	Event: 08/13/2011	Employee Is Killed In Stage Collapse
On August 13, 2011, Employee #1 was killed in a stage collapse. The original abstract had no additional information.		

Table 22 - Inspection Detail (b)

Inspection: 315637181 - I.A.T.S.E. Local 30

Inspection Information - Office: Indiana

Nr: 315637181	Report ID: 0551800	Open Date: 08/17/2011		
I.A.T.S.E. Local 30 1407 East Riverside Drive Indianapolis, IN 46204		Union Status: Union		
SIC: 7922/Theatrical Producers (Except Motion Picture) and Miscellaneous Theatrical Services				
NAICS: 561310/Employment Placement Agencies				
Inspection Type:	Accident			
Scope:	Partial	Advanced Notice:	N	
Ownership:	Private			
Safety/Health:	Safety	Close Conference:	01/26/2012	
Planning Guide:	Safety-Manufacturing	Close Case:	09/23/2013	
Related Activity:	Type Accident	ID 100993740	Safety	Health

Violation Summary

	Serious	Willful	Repeat	Other	Unclass	Total
Initial Violations	4					4
Current Violations						
Initial Penalty	$10,500	$0	$0	$0	$0	$10,500
Current Penalty	$0	$0	$0	$0	$0	$0
FTA Amount	$0	$0	$0	$0	$0	$0

Violation Items

	#	ID	Type	Standard	Issuance	Abate	Curr$	Init$	Fta$	Contest	LastEvent
Deleted	1.	01001	Serious	2200080101	02/08/2012	03/06/2012	$3,500	$3,500	$0	02/29/2012	J - ALJ Decision
Deleted	2.	01002	Serious	19100132 A	02/02/2012	03/20/2012	$3,500	$3,500	$0	02/29/2012	J - ALJ Decision
Deleted	3.	01003	Serious	19100132 D02	02/08/2012	03/26/2012	$3,500	$3,500	$0	02/29/2012	J - ALJ Decision
Deleted	4.	02001	Serious	19040001 A02	02/08/2012	03/26/2012	$1,000	$0	$0	02/29/2012	J - ALJ Decision

Accident Investigation Summary

Summary Nr: 200999407	Event: 08/13/2011	Employee Is Killed In Stage Collapse
On August 13, 2011, Employee #1 was killed in a stage collapse. The original abstract had no additional information.		

The absence of other cases in official OS&H databases is attributable to the reasons the victims were on the site: often they were visitors, festival goers or performers, seldom workers.

4.3.2 In closing

The description has included some level integration of a number of cases that informs the current practice of Safety management. Hence conducting a state-of-the-art review with all these activities serves as a suitable theoretical framework for disseminate in this field a Culture of Safety, in order to inform further research, education and practice in accident causation, prevention and Safety management. Some of the most important questions to answer is the possibility and the limits of learning from past accidents to project useful predictions into the future. Moreover, it is pivotal to understand if complex risks due to multiple factors can be managed through a “reductionist” approach, that is to calculate the total risk as a simple sum

of partial risks, or an “emergentist” approach, according to which in the total resulting risk is somehow higher.

The designed software – for example, are therefore not specific solutions to a particular problem in a unique context, but their aim is to become a generic solution to a set of similar problems. Hence, the designs are demonstrated in different application domains to establish the effectiveness of the solution in different (but similar) contexts without losing its basic effectiveness.

In this solution evaluation, the outcomes of testing allow for further improvement of the proposed designs. This makes design science an iterative process and allows to assess the generalizability of the softwares.

For sure, a widespread Culture of Safety, in peculiar fields like the above described ones, is essential to make involved people aware of the risks they face day by day. It is common that in these situations two practitioners have to cohabit: the Safety expert and the worker.

The job could be so specific, that just the expert worker knows it in every phase and in every procedure, that is it is necessary that both the professionals figures communicate and learn from each other to find a common path not to limit the worker activities, but that ensure his Safety in every phase of the job.

Chapter 5

Development and Evaluation of Contractor Safety Pre-Qualification Tool

Is the Culture of Safety measurable? How can we quantify it?

There is a strong need among owners and general contractors during the project planning phase of a construction site to evaluate potential subcontractors on their capabilities to effectively provide a safer work environment; however, there are no standardized procedures for making decisions about who is best to work with, that is who is pre-qualified. A few new pre-qualification checklists that examine leading indicators of Safety do now exist, even if these programs lack tested validity and often do not capture the Culture of Safety. Effective programs need to include organizational measures based on how leaders and workers together create and react to their social environment. The goal of this study was to develop a pre-qualification assessment tool that demonstrates improvement in the Health and Safety of construction workers through effective systems of Safety that are based on a set of values shared and disseminated throughout an organization, especially the worksite.

This project aim was to develop and validate a new publicly available pre-qualification assessment tool for construction projects that adds evidence-based approaches to the Health and Safety of construction workers in order to select and promote safer contractors. The approach is innovative because it incorporates how organizations value Health and Safety, demonstrated through their organizational structure (e.g., policies and practices), and how those values create a Healthy and safe environment for all workers on a construction site. The new tool should capture contractors' values conveyed in their policies, programs, and practices. This will

enable contractors to maximize systems of Safety in order to better protect the Health and Safety of the construction worksite.

To accomplish this goal, existing pre-qualification practices and organizational theory in relation to Culture of Safety and worksite Safety performance have been evaluated and reviewed. To test the validity of this pre-qualification assessment tool, the group of study implemented the pre-qualification tool for all contractors on 27 construction projects in New England. Safety performance data have been collected, including self-reported worker injury and worksite injury reports, inspection data, and financial data. The hypothesis was that sites with better overall pre-qualification assessment metrics would have had better Safety performance outcomes.

The assessment procedure compiled through a qualitative evaluation and review of current pre-qualification practices and organizational theory and metrics in relation to Culture of Safety and worksite Safety performance, and quantitative analysis of associations between organizational leading indicators and lagging injury indicators reported by some 5,000 contractors within the Construct Secure Database.

5.1 Starting Point

Recent decades have brought large improvements to Health and Safety conditions in the construction industry, yet the number of fatal and non-fatal injuries remains extremely high. To combat this, some employers have implemented Safety incentive programs, such as those that use injury-based Safety performance metrics to evaluate overall worksite Safety and reward workers. However, these lagging indicator-based programs may discriminate against injured workers and may reduce injury reporting.

Approaches to create existing Safety assessment procedures rely heavily on lagging indicators and outcomes with little based on process evaluation and theoretical models of the workplace. A construction worksite is a complex socio-technical system and effective Health and Safety programs need to successfully utilize and interact with the components of this complex system in order to

effectively protect workers' Health and Safety. As an alternative, programs could rely instead on leading indicators of Safety, such as hazard control and other root causes of injuries. However, such complex systems are difficult to measure, and often values of a company and its culture of Safety drive the programs and practices within the complex system. Based on the latest literature, the assessment development incorporates theoretical frameworks of worksites, empirical data from assessment databases, practical experience with assessments, and feasibility to implement the procedures. The proposed approach combines theory with real world practicality in quantifying an organization and its values towards the Safety and Health of all workers on a site; that will make novel and innovative contributions to the construction industry. There is evidence in the construction industry and other fields that Safety climate measures are strong predictors of injury outcomes at the worker level, as well as other Health and Safety outcomes.

In addition, Safety climate may act as a proxy for injury outcomes based on its empirical associations of injury measures (*Clarke, 2006; Huang, 2006*) and the theoretical Safety performance framework of Neal and Griffin.

Studies in other industries have focused on relationships between injury and Safety climate (*Johnson, 2007*), as well as associations between mediating or modifying factors on the pathway of Safety climate and injury such as Safety behavior, employee Safety control, and Safety leadership.

Due to the ever-changing nature of a construction site, the changing potential injury hazards, and the changing workers, the need for effective and predictable Safety management systems is ever present throughout the duration of the project, including the planning phase when changes can be quickly and easily made. Choosing the correct companies who share and prioritize Safety that matches the values and goals of the project will increase success in creating a safe and Healthy working environment

In partnership with individuals from the local construction industry, a cooperation between Universities, group of study and researchers developed assessment procedures that capture how a contractor values the Safety and Health of workers, and how these values are reflected in contractors' systems of Safety. Hence, this study examined how to assess organizational factors or ergonomics that

create a positive Safety climate that in turn improves the Health and Safety of workers. In fact, the goal of modern ergonomics is to optimize system performance and human wellbeing. Study design includes both observational/descriptive and experimental, both in the laboratory and in the real work environment. The proposed study evaluated current prequalification practices and organizational theory and procedures regarding Culture of Safety and worksite Safety performance in order to develop a contractor Safety assessment procedure for pre-qualification purposes, leading to an improvement of worker Health and Safety.

It is important not to neglect expert's current and recent research in construction, including evaluating Health and Safety communication systems on construction worksites, Safety climate and construction Safety assessment program evaluations, and evaluating the use of ladders on commercial construction sites.

5.2 Objectives

The development and evaluation of a pre-qualification assessment procedure that captured various leading indicators of a company's Safety program, are indeed indicators of how the philosophy and values of that company match the project's goals. Since choosing safer contractors is fundamental in creating a safe culture on construction worksites, the contribution of the proposed work is significant because it will expand current methods to incorporate both theory and practice addressing core values that have proven associations with Safety performance outcomes and validate these measures in real work environments. Many existing Safety management assessment procedures that aim to prequalify contractors rely on lagging indicators, such as injury rates and the Experience Modifying Rate (EMR); which, while being important outcome measures of Safety performance, provide little to no information about a company's Safety management systems and are prone to specific weaknesses associated with work-related injury reporting in the construction industry. More recent company assessment Safety programs include a greater number of leading indicators of Safety management systems, with some incorporating automated review of written Safety programs. However, these metrics of Safety management systems have no association with worker self-reported Safety climate metrics on some 27 worksites.

There is evidence about organizational factors that improve worksite Safety within subcontractor and general contractor' companies through the formation of an assessment procedure that accounts for all potential and reasonable factors that could have an effect on Safety.

This proposal addressed several items within NIOSH's National Occupational Research Agenda (NORA), Agenda for Construction related to Strategic and Intermediate Goals: there are positive and negative factors, measurement methods for evaluating Culture of Safety and Safety climate in the construction industry, improvement in the effectiveness of Safety and Health management program, best practices, improvement of Safety and Health performance, analyses of how construction industry complexity and fragmentation can affect them).

Additionally, it is important to assess different Safety roles, responsibilities, interactions, and oversight among the multiple parties involved with complex construction projects. That will result in regular and accelerated construction project lifecycles, and identification of obstacles and opportunities for improving system performance.

5.3. Methods

The approach utilizes a public Health framework for intervention, development that integrates theory and practice to create a new assessment procedure that incorporates the theory of Culture of Safety and its focus on company values with the goal of capturing indicators of Safety values during the process. The research proposed in this application its innovation, because it advances the status quo for pre-qualification Safety assessment procedures in the construction industry by combining organizational and Safety culture/climate theory, empirical data on current pre-qualification databases, and practice program in the real work environment. Moreover, this proposed project validated these procedures through a set of fields testing on some 27 construction sites providing evidence-based approaches to pre-qualification procedures. This approach and innovation is enriched both in Research and in Practice phases, as needed in the construction industry.

5.4. Study design and sample population

The pre-qualification assessment procedure has been designed to capture a company's Safety approach. The procedure aims to reduce workers' injuries by providing owners and construction management companies with the tools necessary to select and build strong partnerships on their worksites, increasing sites' Safety performance.

Assessment of construction Safety programs and the programs themselves needed to be adaptable, comprehensive, and immersed in the very dynamic work environment of construction sites. The hazards and the work environment constantly change, half of the work force on a site turns over every month (*Sparer, 2013*). Such a dynamic environment requires sophisticated systems of Safety that had to be well established, clearly communicated, and consistently observed throughout a worksite. Furthermore, the evaluation of these systems is crucial for continuous improvement to keep Safety programs sustainable and effective.

Organizational models of workplace Safety and Health indicate that Safety practices and resulting injuries and disability are related to the Culture of Safety of the organization (*Amick, 2000; Kines, 2010*); however, current assessment procedures lack the capability of capturing these organizational values effectively. Current methods for capturing the Culture of Safety of an organization examine Safety climate via worker surveys; however, workers come and go on worksites and therefore traditional measures of Safety climate vary greatly.

The metrics is based on organizational indicators of Health and Safety that are being developed for general industry. Central to the success of the project was the established partnership with both owners and construction companies in New England that are critical to the current projects (Denn*erlein, 2011-2012; Dennerlein, 2011-2016*). The team results by the partnerships between three owners: Harvard University, MassPort, and the University of Massachusetts Boston. All have significant construction plans for the following 5 years, especially in the current period of the economy recovering, specifically in the construction industry in New England. In addition, it exists some strong partnerships with a number of construction companies. These include Skanska, Gilbane, Suffolk, Shawmut, Lee Kennedy, Consigli, and JF White, General Contractors who have

enabled the team to implement pilot and research Health and Safety programs on their sites. Through these intervention protocols Authors have gone on site and collected worker surveys of close to 1500 construction workers.

To determine and develop an assessment procedure that captures the values of contractors, resulting in improved workers' Health and Safety performance, authors compiled a checklist/survey-type assessment. This tool was useful to understand the procedure through both a qualitative evaluation and review of the current pre-qualification practices and organizational theory and metrics in relation to Culture of Safety and worksite Safety performance and, a quantitative analysis of associations between organizational leading indicators and lagging injury indicators reported by some 5,000 contractors within the ConstructSecure Database.

The pre-qualification assessment procedure was developed to assess the performance of the procedure on 27 projects, for all the contractors. Safety performance data include administrative data such as injury reports, inspection data, and financial data when available, as well as worker self-reported outcome of Safety climate and injuries. The tested hypothesis was that sites with better overall pre-qualification assessment metrics have better Safety performance outcomes.

The expected outcome of the study is a contractor Safety assessment procedure for pre-qualification that captures contractors' values embedded in their policies, programs, and practices that has been validated and tested on work projects. The impact of this research will lead to the understanding of specific best practice components that are measurable and will lead to better tools to assist in implementing these best practices to protect the Health and Safety of construction workers. To develop the framework and the list of items that will comprise the pre-qualification assessment, authors conducted formative research by using a mixed approach of both qualitative and quantitative methods.

5.5. Treatment conditions

For contractor and workers recruitment, thanks to the longstanding relationships from previous commercial construction research projects, it exists a strong partnership with a number of construction companies. A trained interviewer has gone in person to the construction site to administer the focus groups and key

informant interviews to the contractor management and their respective construction workers. Prior to conduct any interviews, all participants had been read a formal Statement of Consent provided by the interviewer. The completion of the questionnaire indicated that they understood they were participating in a research study, the risks involved in participating, that they could refuse to answer any question that they were not comfortable with, and that the information they provided would have been kept strictly confidential. Their participation in the research aspect of this project did in no way affect their employment status either positively or negatively, in fact written information collected for research purposes did not become part of the mangers or the construction workers personnel records and individual responses were not linked to identifying information (Names and any other identifying information were not collected from the study participants eliminating risks to confidentiality breaches).

5.6. Intervention efficacy evaluation

Through this proposal's first aim, the Safety assessment procedure attempts to capture Culture of Safety as a set of values, attitudes, perceptions, competencies, and patterns of behavior that arise from aspects of a company that include the policies and procedures[8]. Then, the Safety climate - as a quantitative measure - validates it, indeed it successfully incorporates Culture of Safety as part of the developed pre-qualification assessment procedure. These assessments allowed owners and general contractors to pre-qualify contractors resulting in improved Safety performances, predicted by the measurement of worksite Safety climate. The long-term goal was to demonstrate improvement in the Health and Safety of construction workers through effective systems of Safety that are based on a set of values shared and disseminated throughout an organization, especially in the worksite.

5.7. Research design

For development of the assessment procedure used the first five steps of Intervention Mapping as a framework to guide the development of the assessment procedures as the mapping is a systematic process that integrates information from

[8] **.** Commission HaS. *ACSNI Study Group on Human Factors.* London1993

theory, practice, findings reported in the literature, and experience and expertise from targeted populations (*Bartholomew, 1998*).

The framework allowed authors to use a stepwise process to design a procedure and evaluate that procedure to determine the degree to which decisions, assumptions, and expectations about the procedure had been accomplished. For the needs assessment, one of the systematic steps, the team did three activities: review of current and published procedures, formative research of practices and procedures through key informant interviews and focus groups, and data analysis of the large database of construction company Health and Safety programs (ConstructSecure). The goal was to identify both formal and informal procedures that capture a company's Culture of Safety components and other leading indicators of Safety performance.

5.8. Qualitative data collection and analysis

Research team members used a mixture of quantitative and qualitative methods to evaluate the efficacy. Qualitative Analysis, as ethnographic content analysis, a method used in anthropology, to analyze qualitative data that are collected in the form of texts, including notes from.

In addition to the qualitative activities to determine current practices, a quantitative analysis of associations between organizational leading indicators and lagging injury indicators reported by some 5000 contractors within the ConstructSecure_Database. The goal was to utilize the enormous amount of data reported by contractors from across the country and determine the associations between their assessment of Safety management systems as well as their financial system performance (leading indicators) and their injury rates, fatalities, and EMR (lagging indicators). These associations provide information on which metrics best predict the outcomes. In addition, the purpose is to complete a factor analysis to examine groupings of specific metrics within the database.

The Lagging indicators in ConstructSecure - Dependent Variables or outcome variables, used in these proposed analyses are injury rates for

- all recordable injuries;
- injuries involving days away, restricted, or transfer (DART)

experienced by the company for the past three years.

For both, the program takes the number of cases and the number of hours worked for the past three years as entered by the contractor representative and calculates injury rate. In addition, companies enter into the database the number of OSHA citations, as well as uploading an electronic version of the OSHA 300 Summary Form, their EMR certificate.

The Independent Variables - management systems, are a series of questions describing four components of the company's management systems:

1. Safety Management Systems,
2. Safety Program Elements,
3. Special Elements,
4. Financial Assessment Program.

Utilizing the data collected, the study investigators defined outcomes to be predicted by the newly designed assessment procedure and the methods to obtain those outcomes. These outcomes captured relevant factors that influence Safety performance on the site of interest, specifically Safety climate and injury outcomes as well as mediating factors such as organizational practices that influence workers outcomes.

The expected objective contains both organizational and workers outcomes that lead to accidents (based on a conceptual framework) and injuries and to capture these outcomes they expected to measure the values of project leadership from foremen to project executives as well as the values of the workers.

(For example, they knew through Safety climate research that employees can accurately assess organizational policies, practices, and procedures pertaining to the priority of Safety in an organization. Therefore, as an outcome to be predicted by the pre-qualification assessment procedure, Safety climate could be measured using the Dedobbeleer and Beland (*1991*) nine-item Safety climate scale. It measure was

chosen because it is the only measure, to the authors' knowledge, of Safety climate specific to the construction industry. It is important to have industry-specific measures, as the nature of Safety climate in each industry may differ.)

Based on the literature, authors developed a theoretical framework that defined metrics that lead to the outcomes defined in the objectives. They took current/existing frameworks that incorporate theories predicting the specific outcomes. For example, numerous meta-analyses had shown that Safety climate was a leading indicator of workplace Safety outcomes (*Christian, 2009; Beus, 2010; Tang, 2011*).

From this conceptual model derived the assessment procedure based on the theory and the practical-based strategies determined in the needs assessment phase. They expected the procedure to include many factors from the conceptual model measurable through interviews or self-administrated audits.

Once the first assessment procedure had been developed and organized, authors reviewed the procedure with advisory board and industry partners to assure all the components are salient and acceptable, especially with regards to their practicality. The feedback on the content of the assessment procedure are provided as well as the feasibility of testing the procedure in a large-scale observational study.

Lastly and based on the feedback from both the scientific and construction advisory boards, designers created an implementation plan for the adopted procedure, completing a few dry runs with the assessment procedure with the partners including Harvard University (an owner), and construction management companies (e.g., Skanska, Gilbane, Lee Kennedy, and Suffolk Construction). This enabled them to test the mechanics of completing the procedure (e.g., length of time to complete) and its usability.

In order to provide evidence that pre-qualification procedures are valid in terms of predicting Safety performance of a site, data have been collected for 12 months on 27 projects and then associations have been examined using the procedures' metrics and Safety performance metrics, testing the hypothesis that sites with better overall pre-qualification assessment metrics have better Safety performance outcomes.

5.8.1 Quantitative data collection, Worksite recruitment

Authors applied the newly developed pre-qualification assessment procedures on 27 worksites and followed these sites for the duration of the project (or for 12 months, whichever comes first completing repeated measures of pre-qualification procedures and worker survey metrics). At each site, the project management conducted the assessment procedure at the beginning of the study. The project management included the general contractor and all subcontractor project leadership that typically would have completed the qualification procedure during the bidding process.

By collecting data at both the individual and jobsite levels, the team was able to explore the full predictive capabilities of the pre-qualification assessment procedure.

A previous research has indicated that site-attrition in commercial construction is quite high, with approximately 50% of individual workers changing each month; highlighting the importance of multiple site surveys.

Once recruited, they worked with site management to complete the assessment procedure in order to identify key project site mangers from each company on site. Following protocols developed as part of Independent Variable, team members gained as expected the pre-qualification metrics resulting in a sum score of groups of questions to determine values per Constructs or indicators as synthetized in the orange boxes in the following Figure.

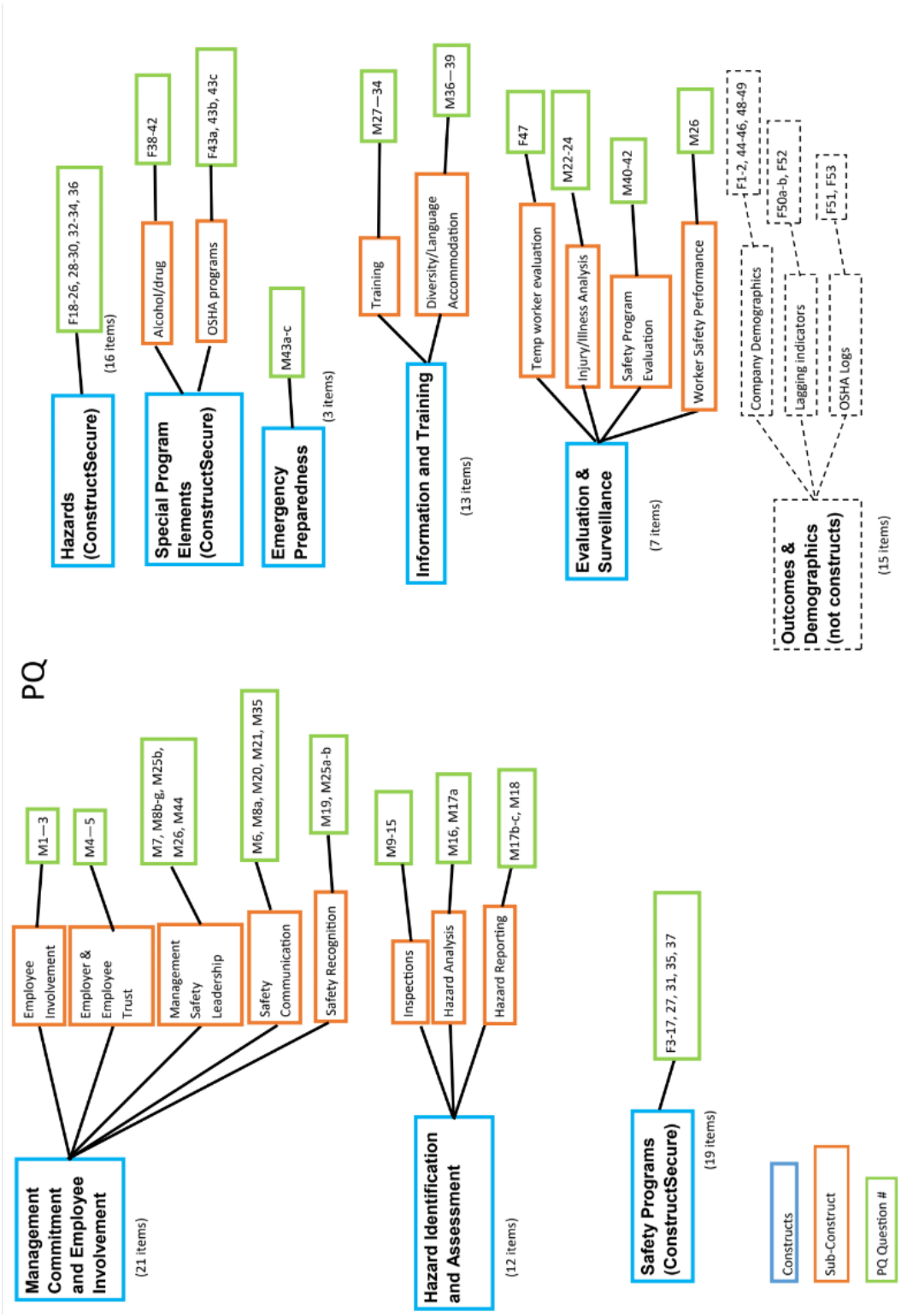


Figure 35 - pre qualification concepts map

Shortly after completing the pre-qualification procedure on a given worksite, a team returned to the site to administer a worker survey to all workers on site. The survey contains primary dependent variable of interest, self-reported musculoskeletal pain and injury, as noted in the conceptual model as the right-most item.

To collect the surveys at each of the 27 sites, the head manager has always advertised the study a few days prior to the site visit through posters, announcements at foremen meetings, and phone calls to on-site management.

The team approached workers during coffee and lunch breaks and conduct surveying in teams of two/three. One person standing in a central on-site location (typically near the lunch truck or break room) and another person walking the site to ensure that all eligible workers are captured. This method has proven effective in other survey-based research conducted by the group. Workers have been provided with a $10 gift card for participating and have been reminded that the survey is voluntary, anonymous, and strictly confidential. The questionnaire was self-administered and paper-based, taking between 10 and 15 minutes to complete (ANNEX 1). It is in English and designed for an 8th grade reading level. The surveys were open to all workers at the targeted sites, the aim was to collect surveys from at least 27 sites from at least 5 General Contractors in order to capture a variety of trades.

Administrative data, including both injury and project financial and planning data, have been collected monthly by other partners as part of their management systems. Once collected, authors retrieved the data for the database (including Injury data - the number of days away, restricted or transferred (DART) injury cases, the number of OSHA recordable cases, the number of medical only cases, as well as the number of project hours worked in order to calculate the injury rates). The financial data to be collected include cost overruns, an assessment of the project schedule, and the total revenue generated from the project by the general contractor, but that was not analyzed at this part of the project.

Both owners and construction management companies/general contractors, 27 worksites have been recruited. Site inclusion criteria included an injury/incident reporting system, project duration of at least 6 months, and a project budget of at least $10 million. Authors aimed to recruit a range of projects in terms of total cost, workforce composition and numbers, scope of work, and union/non-union status in

order to have a high level of variability in the data also seen the successful results gained in recruiting sites in the past.

Table 23 - Workers Survey

1346	Workers
159	Companies
27	Sites
10	General contractors

Team members scheduled a day to conduct the survey on a job site being sure about the presence of a Safety manager or a supervisor on site underlining the relevant information of the survey. Usually the surveys have been conducted before the opening of the construction site, during the coffee break and at lunch time. After collecting all completed surveys at intervention sites the data were collected, organized and inserted on the database.

Workers aged 18–65 who could read and write English were eligible for the survey, other demographic information were collected. Authors did not collect and compared names from survey respondents to track workers.

The workers have been classified per worksite and Company, as shown by the following Figure where the horizontal axis describes the number of workers per company (wpc), while the vertical axis shows their distribution.

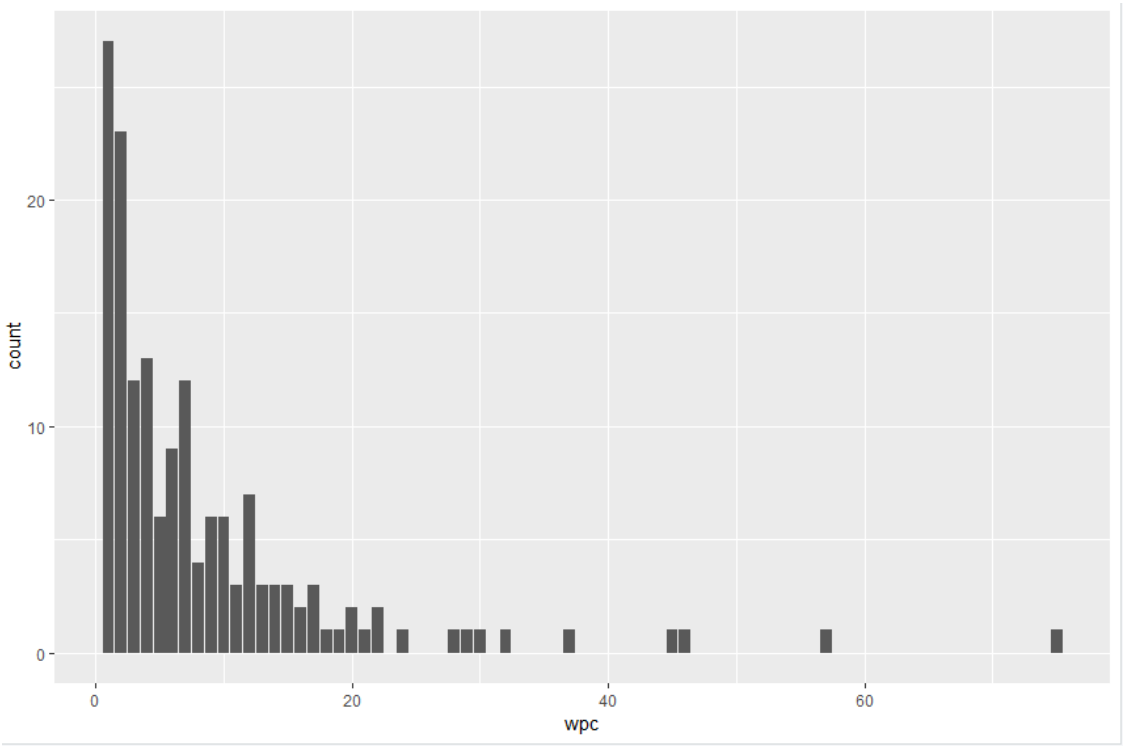


Figure 36- companies distribution per number of workers

The study sample included only those companies having at least 3 workers, in order to have a better representativeness and not to exclude too many workers.

The following Figure shows the distribution of workers in companies composed by less than 3 workers (left bar), and those having 3 or more workers.

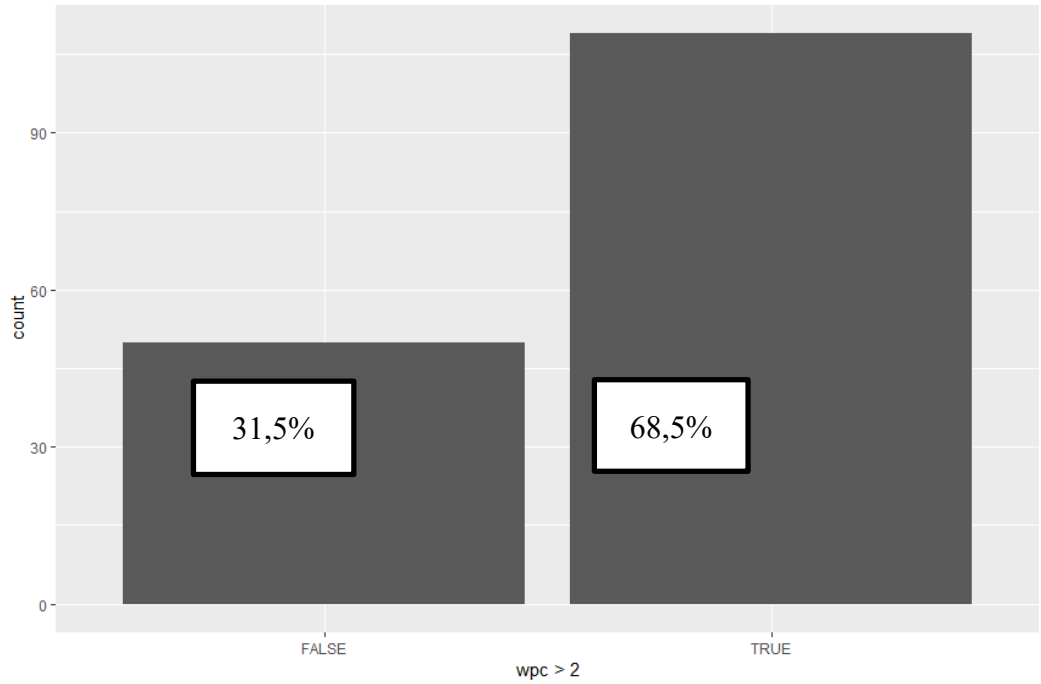


Figure 37 - Percentage of companies having more than 2 workers

The size of worksites and workers' characteristics differed between each intervention sites despite randomization. All sites were approximately hosting more than 10 workers, the number in the following Table represents the number of workers who completed the survey, there is no evidence of the total workers in every site the day of the data collection, so it is not possible to know the rate of workers who voluntarily accepted to answer.

Table 24 - worksites decrescent distribution per number of workers

	site_id	wps
1	7	165
2	10	160
3	9	150
4	3	84
5	16	75
6	14	73
7	6	72
8	17	67
9	1	49

	site_id	wps
10	12	48
11	11	45
12	5	42
13	21	42
14	8	36
15	19	31
16	2	28
17	23	26
18	18	25

	site_id	wps
19	22	22
20	13	20
21	15	19
22	20	19
23	56	16
24	25	15
25	24	12
26	26	4

The survey captured workers' age in years, gender, union membership status, specific trade, job title, tenure in the construction industry in years, and highest educational attainment. The combined responses of the two race and ethnicity questions indicated non-Hispanic (includes Black/African-American, Asian, and Native American), White or other (includes Hispanic and respondents who indicated "other") qualitative data collection and analysis.

Table 25 - Worker Demographics

	WORKSITES	COMPANIES
TOTAL	1426	635
WORKERS PER	59 (46.38)	14 (12.65)
	1330	598
AGE	40 (11.25)	40 (11.3)
GENDER	1360	610
MALE	1281 (94%)	575 (94%)
FEMALE	70 (5%)	27 (4%)
OTHER	9 (1%)	8 (1%)
RACE/ETHNICITY	1349	605

HISPANIC OR LATINO	111 (8%)	38 (6%)
WHITE	970 (72%)	455 (75%)
BLACK	162 (12%)	66 (11%)
NATIVE HAWAIIAN	4 (1%)	3 (0.5%)
ASIAN	16 (1%)	9 (1.5%)
AMERICAN INDIAN	26 (2%)	6 (1%)
OTHER	60 (4%)	23 (4%)
JOB TITLE	1351	612
FOREMAN	250 (18%)	120 (20%)
APPRENTICE	295 (22%)	136 (22%)
JOURNEYMAN	676 (50%)	290 (47%)
OTHER	130 (10%)	66 (11%)
UNION	1362	615
MEMBER	1200 (88%)	551 (90%)
NON-MEMBER	162 (12%)	63 (10%)

Workers on sites differed in terms of age, industry tenure, trade, and job title, as well as in terms of month started on-site and total time on-site.

When the study initiated in 2016, a Safety climate questionnaire has been developed by the research group for use within the construction industry given the importance of using an industry-specific scale to describe the Safety climate (*Zohar, 2010*). The questions were indirectly based on Zohar's original 40-item and 8-factor scale (*Zohar, 1980; Brown, 1986; Gillen, 2002*) used the Dedobbeleer and Béland items as a single factor to measure Safety climate within a cohort of construction workers and found a positive association between Safety climate and injury severity.

As seen in the green boxes of the following Figure, the scores per Construct (indicators) were obtained through the average of a group of questions. Workers were automatically excluded if they answered less than half of questions per Construct.

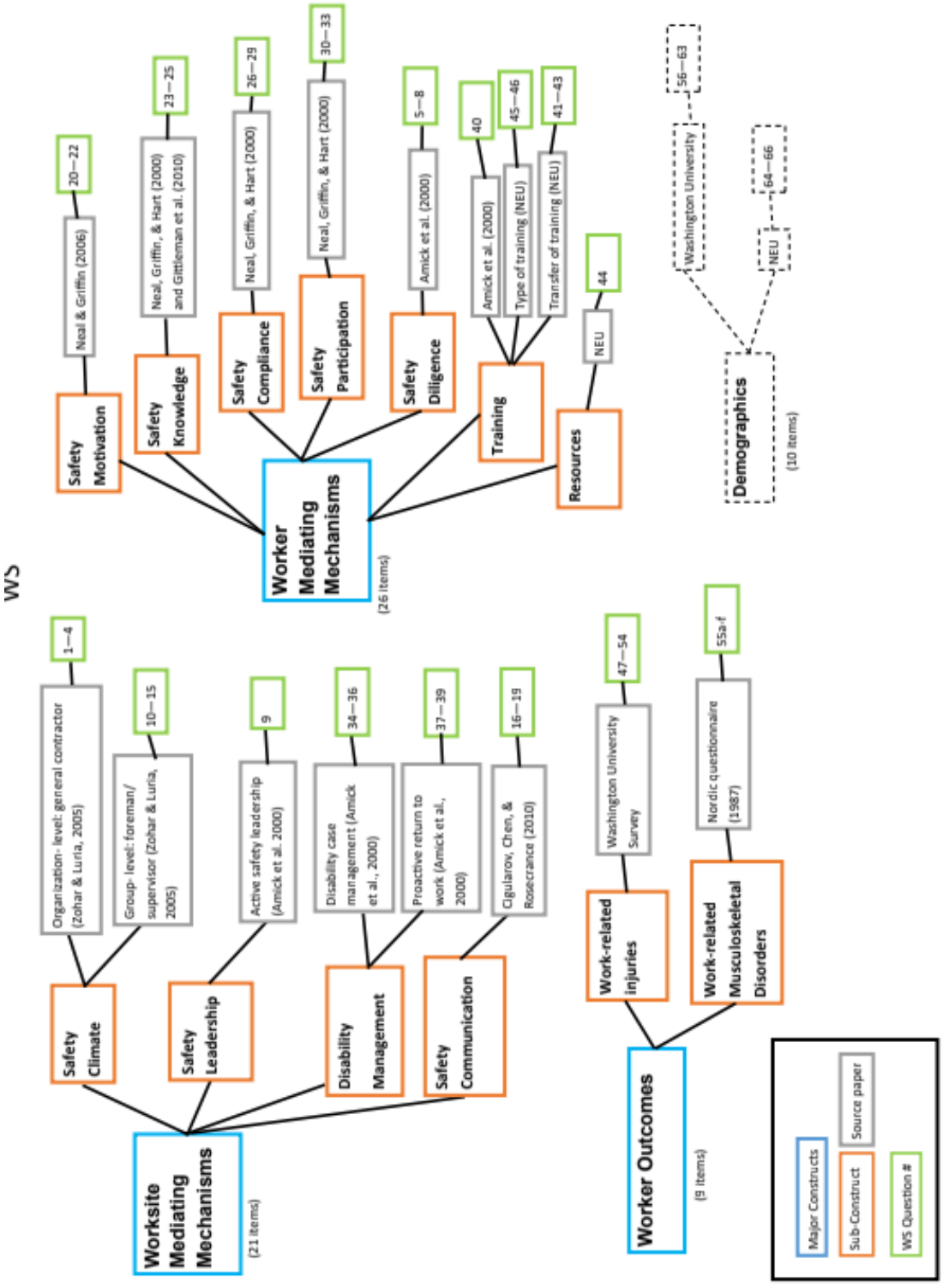


Figure 38 - Workers Survey concepts map

During the development of the assessment procedure, authors completed much of the qualitative data collection and complete the data analysis of the empirical database of 5,000 companies' Safety program descriptions and their injury outcomes occurred Years 1 and 2. The evaluation and the feasibility of the procedures and the recruitment on 27 construction worksites occurred in Years 3 and 4, and I actively participated in the last phase, the analysis of the gained results and findings during the last year as a first step to their dissemination – Year 5.

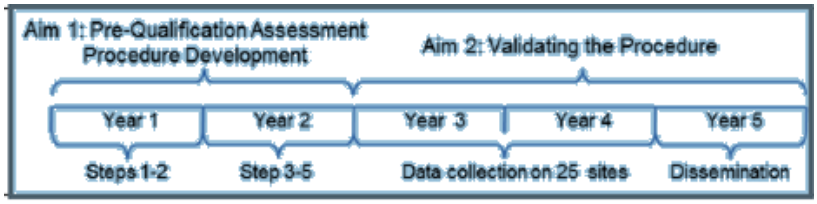


Figure 39 - A Chrono program of the project

Researchers had developed a scoring rubric where each item was given a value between 1 to 5 and then summed for a total score. As a result each item was equally weighted. Higher scores indicated a positive Safety climate. The number of response options per item in the original scale varied from item to item (all having five responses, but some a positive meaning, other a negative one), the point contribution reflected this. For example, for any item had five possible responses, the point contribution to the overall score would be 0, 1, 2, 3, 4 or 5, whereas if other responses options were present, the contribution would be reversed or qualitative.

The study, then aimed to understand the company score, so the average of each worker's Construct score with his colleagues (weighted on the effective number of workers considered – excluding those who didn't answer to half of questions) has been calculated.

Table 26- criteria for exclusion of workers in the company's average score per construct

COMPANY		SAFETY CLIMATE ORGANIZATION LEVEL			SAFETY CLIMATE GROUP LEVEL			SAFETY LEADERSHIP		
ID	N° of workers	NA	workers	mean	NA	workers	mean	NA	workers	mean
A.	**32**	0	32	4,35	3	29	4,23	- 10	22	4,23
B.	**28**	0	28	4,76	1	27	4,29	- 3	25	4,6
C.	**22**	0	22	4,24	2	20	4,15	- 2	20	4,25
D.	**13**	0	13	4,67	0	13	4,30	- 2	11	4,36
E.	**11**	0	11	4,09	0	11	3,80	- 2	9	4

F.	**22**	0	22	3,57	0	22	4,25	- 2	20	4
G.	**57**	0	57	4,17	0	57	4,05	- 2	55	4,27
H.	**7**	- 2	5	4,08	0	7	3,81	- 2	5	4
I.	**5**	- 1	4	4,25	0	5	4,07	- 2	3	4
J.	**12**	0	12	4,52	0	12	4,24	- 1	11	4,36
K.	**20**	0	20	2,95	1	19	3,64	- 1	19	3,10

The following Table describes the final scores obtained in the Worker Survey per Worksite and per Company.

Table 27 - Work Site Data

	WORKSITES	**COMPANIES**
TOTAL	19	43
SAFETY CLIMATE		
WORKSITE (SC.OL)*	4.08 (0.33)	4.12 (0.39)
SUB CONTRACTOR (SC.GL)**	4.09 (0.29)	4.09 (0.35)
ACES SCORE	42.45 (3.75)	42.18 (6.51)
LAGGING INDICATORS		
INJURY RATE (/100 FTE)***	3.27 (5.12)	2.02 (2.31)
DART RATE (/100FTE)	1.55 (2.98)	2.39 (3.27)
EMR******	NA	0.86 (0.27)
OSHA VIOLATIONS	18	19
0	9 (50%)	18 (95%)
1	4 (20%)	1 (5%)
2	0	0
3 OR MORE	5 (30%)	0

*SC.OL	Safety Climate – Organization Level
**SC.GL	Safety Climate – Group Level
***FTE	Full-time equivalent or whole time equivalent is a unit that indicates the workload of an employed person in a way that makes workloads or class loads comparable across various contexts.
****EMR	Experience Modifying Rate

Depending on whether covariates are treated as dichotomous or continuous variables, and depending on the distributions of the variables, preliminary investigation of associations were explored graphically, and they evaluated Pearson, Kendall or Spearman correlations, rank-based Spearman correlation testing, a non-parametric test used to measure the degree of association between two variables at least ordinal.

The following formula is used to calculate the Spearman rank correlation (*Lehman, 2005*):

$$\rho = 1 - \frac{6\sum d_i^2}{n(n^2-1)}$$

ρ= Spearman rank correlation

d_i= the difference between the ranks of corresponding variables

n= number of observations

Key Terms

Effect size: Cohen's standard may be used to evaluate the correlation coefficient to determine the strength of the relationship, or the effect size.

Correlation coefficients between variables

10 - 29	small association
30 - 49	medium association
50 and above	a large association or relationship

Ordinal data: In an ordinal scale, the levels of a variable are ordered such that one level can be considered higher/lower than another. However, the magnitude of the difference between levels is not necessarily known or quantifiable.

Authors examined the variability of the pre-qualification scores within companies, as well as between companies. They also explored separate models that use the general contractor pre-qualification score as a predictor and the various subcontractor scores as a predictor, as well as a weighted average of the general contractor and subcontractor scores as predictors. Similar analyses also took place for the secondary outcomes of interest, self-reported injury and pain, project financial score, and Safety inspection data.

The power calculations focus on the goal to capture the associations between a developed pre-qualification score and psychometric scores of construction workers.

5.9. Safety climate

The measure the Safety climate score of every site resulted from the mean of every workers' answer per sub construct and then per construct, as described in the

Concept map. Scores of the Workers Survey have subsequently been compared to Pre-qualification's ones, resulting in a correlation TABLE.

The scores of Constructs and Sub-Constructs, resumed in the following table 28, have been compared to each other giving in interesting results.

Table 28 - Correlation Table

	workers_	scol_mea	scgl_mea	sl_mean_	dmdc_m	dmpr_me	sco_mea	sm_mean	sk_mean	sc_mean	sp_mean	sd_mean	r_mean_	workers_	A1_perc	A2_perc	A3_perc	A4_perc	A5_perc	B1_perc	B2_perc	B3_perc	C_percol	D_percol	E1_perc	E2_perc	F_percol	G1_perc	G2_perc	H2_perc
workers_	1	-0,043	0,0818	0,1808	0,1352	0,0302	-0,186	-0,195	-0,059	-0,013	-0,057	0,1138	0,0007	-0,199	-0,175	-0,024	0,0868	-0,041	0,2451	-0,122	0,0527	-0,024	0,075	0,157	-0,024	-0,108	-0,026	0,0344	-0,122	-0,014
scol_mea	-0,043	1	0,4102	0,3641	0,3693	0,5002	0,0892	0,5835	0,4625	0,4132	0,4521	0,426	0,5504	-0,192	0,1328	-0,111	-0,018	0,0262	0,0402	-0,121	-0,31	-0,165	0,0242	-0,085	-0,193	-0,232	-0,136	0,194	0,1692	0,0507
scgl_mea	0,0818	0,4102	1	0,5571	0,4886	0,4544	0,5003	0,4197	0,5176	0,6399	0,6086	0,4379	0,6482	-0,163	0,4292	-0,255	0,0405	0,3427	0,24	0,1484	-0,107	-0,16	0,2968	-0,066	-0,132	-0,169	0,2829	0,2369	0,2988	0,3609
sl_mean_	0,1808	0,3641	0,5571	1	0,5335	0,4287	0,2411	0,3084	0,3737	0,428	0,397	0,8426	0,6363	0,0213	0,282	-0,342	0,2256	0,1767	0,2513	0,003	0,04	-0,009	0,3722	-0,231	0,1158	-0,083	0,3611	0,3067	0,0034	0,2347
dmdc_m	0,1352	0,3693	0,4886	0,5335	1	0,7925	0,0263	0,2937	0,4571	0,4995	0,5574	0,3686	0,5085	-0,086	0,2114	-0,448	0,0453	0,3507	0,3835	-0,082	-0,175	-0,212	0,2111	-0,015	-0,003	-0,21	0,1147	0,2759	0,1797	0,3298
dmpr_me	0,0302	0,5002	0,4544	0,4287	0,7925	1	-0,052	0,2672	0,3801	0,4016	0,4961	0,2934	0,4299	-0,086	0,1045	-0,478	0,0664	0,268	0,3425	-0,183	-0,223	-0,21	0,1671	-0,082	0,0468	-0,184	0,0444	0,3914	0,2132	0,2785
sco_mea	-0,186	0,0892	0,5003	0,2411	0,0263	-0,052	1	0,3998	0,4027	0,4903	0,4865	0,311	0,382	0,0528	0,3813	0,1003	0,0708	0,1615	0,0859	0,2683	-0,012	-0,093	0,3481	-0,184	-0,125	0,0557	0,3946	0,1858	0,2506	0,2595
sm_mean	-0,195	0,5835	0,4197	0,3084	0,2937	0,2672	0,3998	1	0,8351	0,5903	0,4805	0,4461	0,5582	-0,171	0,0743	0,01	0,0831	0,1754	0,0407	0,0229	-0,066	-0,126	0,1328	-0,127	-0,214	-0,044	-0,067	0,1675	0,1559	0,1863
sk_mean	-0,059	0,4625	0,5176	0,3737	0,4571	0,3801	0,4027	0,8351	1	0,809	0,6909	0,4314	0,6867	-0,314	0,1354	-0,091	0,0717	0,2979	0,1706	0,0764	-0,144	-0,277	0,2817	-0,073	-0,095	-3E-04	-0,07	0,1603	0,1986	0,2698
sc_mean	-0,013	0,4132	0,6399	0,428	0,4995	0,4016	0,4903	0,5903	0,809	1	0,8617	0,4798	0,6694	-0,153	0,1249	-0,236	-0,049	0,217	0,1328	-0,002	-0,403	-0,442	0,327	-0,056	-0,137	-0,065	-0,023	0,0765	0,1107	0,2416
sp_mean	-0,057	0,4521	0,6086	0,397	0,5574	0,4961	0,4865	0,4805	0,6909	0,8617	1	0,3374	0,6875	-0,102	0,2276	-0,297	-0,076	0,2099	0,2085	0,0503	-0,299	-0,32	0,3567	-0,092	-0,065	0,0112	-0,045	0,0983	0,1504	0,2889
sd_mean	0,1138	0,426	0,4379	0,8426	0,3686	0,2934	0,311	0,4461	0,4314	0,4798	0,3374	1	0,6361	0,0993	0,1244	-0,249	0,1692	0,1054	0,0755	-0,034	-0,076	-0,103	0,2925	-0,254	0,0522	-0,053	0,3351	0,2951	-0,025	0,1635
r_mean_	0,0007	0,5504	0,6482	0,6363	0,5085	0,4299	0,382	0,5582	0,6867	0,6694	0,6875	0,6361	1	-0,035	0,2309	-0,281	0,0441	0,2369	0,1866	-0,121	-0,209	-0,196	0,3749	-0,085	-0,21	-0,167	0,1777	0,2368	0,0904	0,1496
workers_	-0,199	-0,192	-0,163	0,0213	-0,086	-0,086	0,0528	-0,171	-0,314	-0,153	-0,102	0,0993	-0,035	1	-0,209	0,1714	0,1103	-0,142	-0,066	0,0831	-0,019	0,1694	0,0589	-0,021	0,127	0,0719	0,2386	0,1341	-0,197	-0,083
A1_perc	-0,175	0,1328	0,4292	0,282	0,2114	0,1045	0,3813	0,0743	0,1354	0,1249	0,2276	0,1244	0,2309	-0,209	1	-0,075	0,1597	0,4461	0,2562	0,5432	0,2204	0,2704	0,4879	-0,133	0,278	0,1739	0,3409	0,3325	0,3085	0,5342
A2_perc	-0,024	-0,111	-0,255	-0,342	-0,448	-0,478	0,1003	0,01	-0,091	-0,236	-0,297	-0,249	-0,281	0,1714	-0,075	1	0,3328	-0,026	-0,093	0,29	0,2913	0,3586	-0,008	0,0268	-0,021	0,0896	0,0886	-0,2	-0,052	-0,163
A3_perc	0,0868	-0,018	0,0405	0,2256	0,0453	0,0664	0,0708	0,0831	0,0717	-0,049	-0,076	0,1692	0,0441	0,1103	0,1597	0,3328	1	0,3668	0,6028	0,3292	0,3888	0,4994	0,363	0,0088	0,3558	0,0328	0,4875	0,3071	-0,18	0,4167
A4_perc	-0,041	0,0262	0,3427	0,1767	0,3507	0,268	0,1615	0,1754	0,2979	0,217	0,2099	0,1054	0,2369	-0,142	0,4461	-0,026	0,3668	1	0,3999	0,2337	0,076	0,0878	0,4812	-0,241	0,2598	-0,072	0,455	0,321	0,0739	0,5921
A5_perc	0,2451	0,0402	0,24	0,2513	0,3835	0,3425	0,0859	0,0407	0,1706	0,1328	0,2085	0,0755	0,1866	-0,066	0,2562	-0,093	0,6028	0,3999	1	0,1026	0,1306	0,1518	0,4138	-0,017	0,2963	0,0526	0,4256	0,3954	-0,053	0,6945
B1_perc	-0,122	-0,121	0,1484	0,003	-0,082	-0,183	0,2683	0,0229	0,0764	-0,002	0,0503	-0,034	-0,121	0,0831	0,5432	0,29	0,3292	0,2337	0,1026	1	0,4575	0,453	0,3585	-0,151	0,6098	0,4134	0,2689	0,0571	0,2575	0,4202
B2_perc	0,0527	-0,31	-0,107	0,04	-0,175	-0,223	-0,012	-0,066	-0,144	-0,403	-0,299	-0,076	-0,209	-0,019	0,2204	0,2913	0,3888	0,076	0,1306	0,4575	1	0,7327	0,1502	-0,111	0,2875	0,2425	0,2488	0,0363	-0,03	0,1322
B3_perc	-0,024	-0,165	-0,16	-0,009	-0,212	-0,21	-0,093	-0,126	-0,277	-0,442	-0,32	-0,103	-0,196	0,1694	0,2704	0,3586	0,4994	0,0878	0,1518	0,453	0,7327	1	0,173	-0,011	0,2884	0,1138	0,3185	0,0642	-0,22	0,0297
C_percol	0,075	0,0242	0,2968	0,3722	0,2111	0,1671	0,3481	0,1328	0,2817	0,327	0,3567	0,2925	0,3749	0,0589	0,4879	-0,008	0,363	0,4812	0,4138	0,3585	0,1502	0,173	1	-0,355	0,3842	0,1006	0,5318	0,4468	-0,017	0,5167
D_percol	0,157	-0,085	-0,066	-0,231	-0,015	-0,082	-0,184	-0,127	-0,073	-0,056	-0,092	-0,254	-0,085	-0,021	-0,133	0,0268	0,0088	-0,241	-0,017	-0,151	-0,111	-0,011	-0,355	1	-0,298	-0,212	-0,377	-0,155	-0,212	-0,28
E1_perc	-0,024	-0,193	-0,132	0,1158	-0,003	0,0468	-0,125	-0,214	-0,095	-0,137	-0,065	0,0522	-0,21	0,127	0,278	-0,021	0,3558	0,2598	0,2963	0,6098	0,2875	0,2884	0,3842	-0,298	1	0,3678	0,193	0,1543	0,0869	0,4203
E2_perc	-0,108	-0,232	-0,169	-0,083	-0,21	-0,184	0,0557	-0,044	-3E-04	-0,065	0,0112	-0,053	-0,167	0,0719	0,1739	0,0896	0,0328	-0,072	0,0526	0,4134	0,2425	0,1138	0,1006	-0,212	0,3678	1	0,0625	0,1598	0,3092	0,1553
F_percol	-0,026	-0,136	0,2829	0,3611	0,1147	0,0444	0,3946	-0,067	-0,07	-0,023	-0,045	0,3351	0,1777	0,2386	0,3409	0,0886	0,4875	0,455	0,4256	0,2689	0,2488	0,3185	0,5318	-0,377	0,193	0,0625	1	0,5023	0,0413	0,431
G1_perc	0,0344	0,194	0,2369	0,3067	0,2759	0,3914	0,1858	0,1675	0,1603	0,0765	0,0983	0,2951	0,2368	0,1341	0,3325	-0,2	0,3071	0,321	0,3954	0,0571	0,0363	0,0642	0,4468	-0,155	0,1543	0,1598	0,5023	1	0,1824	0,4457
G2_perc	-0,122	0,1692	0,2988	0,0034	0,1797	0,2132	0,2506	0,1559	0,1986	0,1107	0,1504	-0,025	0,0904	-0,197	0,3085	-0,052	-0,18	0,0739	-0,053	0,2575	-0,03	-0,22	-0,017	-0,212	0,0869	0,3092	0,0413	0,1824	1	0,0952
H2_perc	-0,014	0,0507	0,3609	0,2347	0,3298	0,2785	0,2595	0,1863	0,2698	0,2416	0,2889	0,1635	0,1496	-0,083	0,5342	-0,163	0,4167	0,5921	0,6945	0,4202	0,1322	0,0297	0,5167	-0,28	0,4203	0,1553	0,431	0,4457	0,0952	1
H3_perc	-0,295	0,1317	0,0814	0,0245	0,17	0,1207	0,1291	0,0187	0,1443	0,0856	0,1497	-0,094	0,1038	-0,096	0,4919	-0,179	0,0804	0,3272	0,2638	0,4121	-0,03	0,0368	0,3152	-0,234	0,3412	0,1856	0,1994	0,2928	0,3891	0,4051
H4_perc	-0,105	-0,309	-0,304	-0,343	-0,503	-0,454	0,0361	-0,213	-0,209	-0,284	-0,246	-0,255	-0,215	0,2224	-0,366	0,3804	0,085	-0,321	-0,285	0,0835	0,1552	0,0958	-0,19	0,0773	-0,15	0,0092	-0,055	-0,389	-0,286	-0,341

Table 29 - Workers Survey Constructs

WORKER SURVEY	scol_mean_percompany	Safety climate organization-level
	scgl_mean_percompany	Safety climate group-level
	sl_mean_percompany	Safety leadership
	dmdc_mean_percompany	Disability - case management
	dmpr_mean_percompany	Disability - proactive return
	sco_mean_percompany	Safety communication
	sm_mean_percompany.x	Safety motivation
	sk_mean_percompany	Safety knowledge
	sc_mean_percompany	Safety compliance
	sp_mean_percompany	Safety participation
	sd_mean_percompany	Safety diligence
	r_mean_percompany	Resources

Table 30 - Pre Qualification Constructs

PREQUAL	A1_percompany	Employee involvement
	A2_percompany	Employer & employee trust
	A3_percompany	Management Safety leadership
	A4_percompany	Safety communication
	A5_percompany	Safety recognition
	B1_percompany	Inspections
	B2_percompany	Hazard analysis
	B3_percompany	Hazard reporting
	C_percompany	Safety programs
	D_percompany	Hazards
	E1_percompany	Alcohol and drug
	E2_percompany	Osha programs
	F_percompany	Emergency preparedness
	G1_percompany	Training
	G2_percompany	Diversity language
	H1_percompany	Temp worker evaluation
	H2_percompany	Injury illness analysis
	H3_percompany	Safety program evaluation
	H4_percompany	Worker Safety performance

Some result, in particular the analysis between Construct of the same Survey, highlighted the coherence between scores of different indicators.

A couple of examples are the *Safety climate organization-level* and the *Safety climate group-level,* having an index of more than 0.5, as shown in Table 31, and the *Disability case management* and the *Disability proactive return,*

Table 31 - Safety climate organization-level vs the Safety climate group-level

	scol_mean_percompany	scgl_mean_percompany
scol_mean_percompany	1.00000000	0.5486736
scgl_mean_percompany	0.54867359	1.0000000

Table 32 - Disability case management and the Disability proactive return

	dmdc_mean_percompany	dmpr_mean_percompany
dmdc_mean_percompany	1.0000000	0.88571758
dmpr_mean_percompany	0.8857176	1.00000000

The diagrams resulting are even more explicative of the situation as shown in the following related figures.

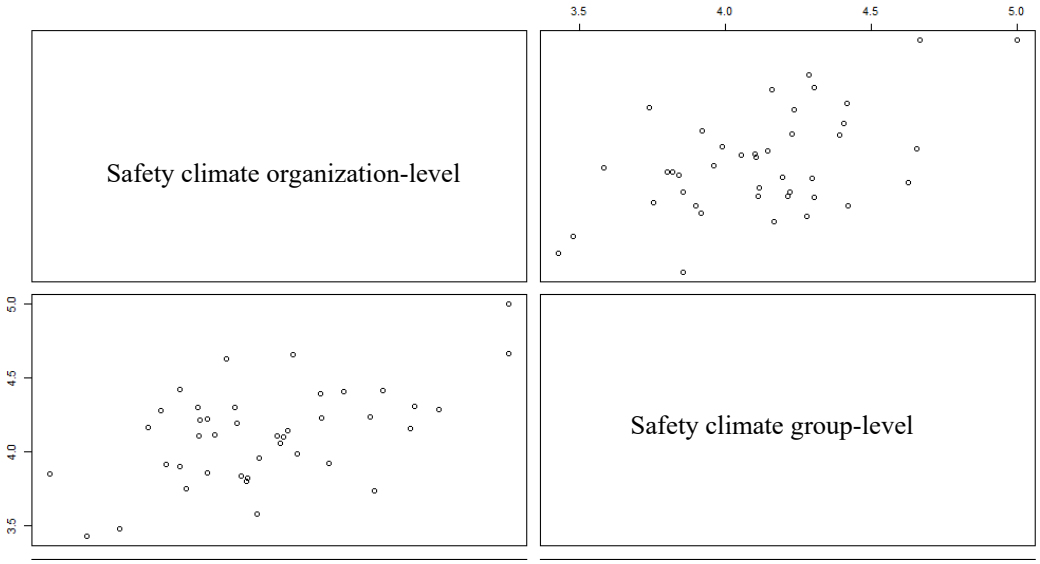


Figure 40 - Safety climate organization-level vs the Safety climate group-level

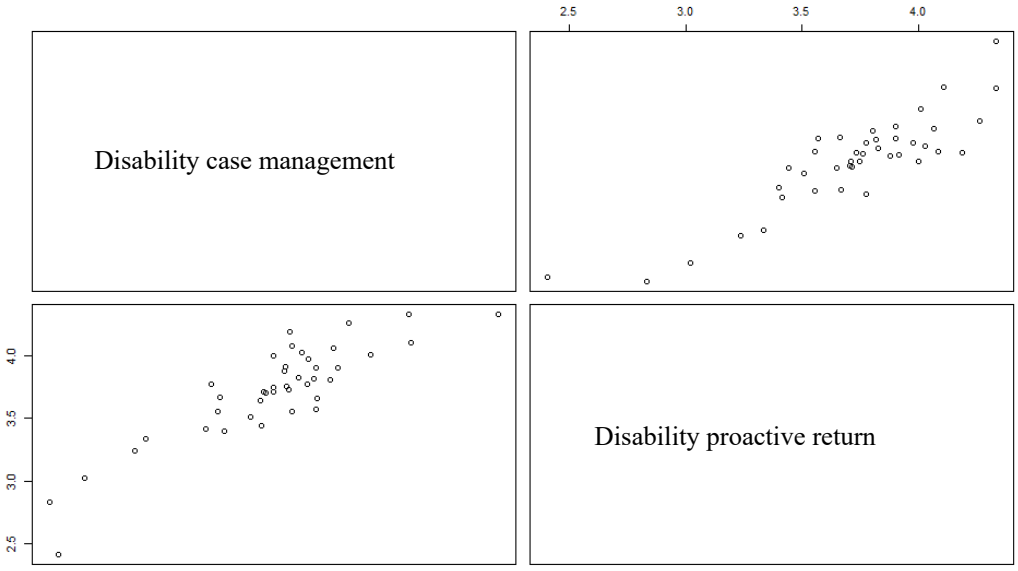


Figure 41 - Disability case management and the Disability proactive return

For ACES Worker Survey correlations, the study only looked at correlations with worksite values for Safety Climate, Injury Rate, EMR and OSHA whereas for the ACES sc we're looking at correlations with company values.

Table 33 Correlations between ACES and Lagging Indicators –

	$ACES_{WS}$	$ACES_{SC}$
TOTAL	24	43
SAFETY CLIMATE		
WORKSITE (SC.OL)	0.58 [0.23, 0.8]; 0.003	0.026 [-0.28, 0.32]; 0.9
SUB CONTRACTOR (SC.GL)	0.58 [0.22, 0.8]; 0.004	0.12 [-0.18, 0.41]; 0.4
INJURY RATE (/100 FTE)	0.14 [-0.37, 0.58]; 0.6	-0.41 [-0.79, 0.22]; 0.22
DART RATE (/100FTE)	-0.074 [-0.55, 0.44]; 0.8	0.35 [-0.25, 0.75]; 0.2
EMR	NA	-0.26 [-0.56, 0.1]; 0.2
OSHA VIOLATIONS	0.17 [-0.31, 0.58]; 0.5	-0.37 [-0.7, 0.1]; 0.1

Table 34 - Regression outcomes

	$ACES_{WS}$	$ACES_{SC}$
TOTAL	24	43
SAFETY CLIMATE		
WORKSITE (SC.OL)	0.072 [0.02, 0.12] p = 0.012	0.002 [-0.018, 0.022] p = 0.85
SUB CONTRACTOR (SC.GL)	0.052 [0.01, 0.10] p = 0.032	0.005 [-0.012, 0.023] p = 0.56
INJURY RATE (PER 100 FTES)	-0.11 [-0.24, 0.034] p = 0.12	--
DART RATE (PER 100FTES)	-0.32 [-0.46, -0.18] p < 0.001	--

There is an association between Safety Climate and the ACES score (obtained by the prequalification) is evident with Worksites and not with companies scores, which is what was seen on Sparer paper (Sparer, 2013).

The reason for this could be that companies follow General Contractor rules and if the General Contractor has high Safety Climate and ACES score, it usually means that the companies will follow their practices to have a high Safety Climate on site.

5.10 In closing

The development and validation of a new publicly available pre-qualification assessment tool for construction projects that adds evidence-based approaches to the Health and Safety of construction workers is a first objective step to select and promote safer contractors. The approach is innovative because it incorporates how organizations value Safety and Health, demonstrated through their organizational structure (e.g., policies and practices), and how those values create a Healthy and safe environment for all workers on a construction site. The expectation is that the new tool, refined and further tested, will capture contractors' values conveyed in their policies, programs, and practices. This will enable contractors to maximize systems of Safety in order to reach a higher occurrence of positive Safety-related themes of teamwork and increased awareness at sites, to better protect the Health and Safety of the construction worksite being more competitive. These improved Safety metrics may lead to reduced rates of work-related injury.

Chapter 6

Safety & Innovation

Does the Culture of Safety need to keep up with the times?

6.1 Background

Nowadays we are facing the 4th industrial revolution, an era of deep changes and innovation in our Society, mostly due to the progress of general welfare and the dissemination of technologies day by day more accessible for all the population. However, the data available in statistical databases on work-related accidents and Health impairments show still frequency indexes which do not reflect this positive improvement, with a not encouraging trend, particularly in some NACE sectors.

That is probably due to a disconnected evolution of technologies available and workforce preparedness, not always sufficient to face the new exigencies or skills to use machinery or work in ultra-specialized sectors.

In this scenario, it becomes important to involve all the actors in the OS&H management, who often operate in a context lacking of a widespread Culture of Safety, and not in tune with the multidisciplinary research results that would be essential to understand in depth the specific work related Safety and Health criticalities of modern industrial and construction activities, and to identify the suitable countermeasures (*Patrucco, 2014*; De Cillis et al. 2017).

To focus on the disconnection between Innovation and Safety, it was decided to follow up the initiative started last year and, in the same vein of that International Meeting*, planned* to deal with innovation in technologies and equipment in underground and infrastructural operation. the attention was focused on the 4th industrial revolution, with a glance to the whole National industrial panorama.

6.1.2 State of the Problem: Data Analysis

The analyses of the OS&H injuries and Health Impairments trends have been the cue to draw a realistic picture of a situation influenced by several hidden parameters often more numerous than the obvious ones. The number of victims connected to the work had been considered a “necessary condition” until the end of the past century, typically in underground operations. On the heel of the impressive progress of the technologies and the automation of some processes, there were positive results even in this field.

In fact, during three eras of automation machines take away the dirty, dangerous, onerous, dull work and decisions, to make better choices avoiding human errors.

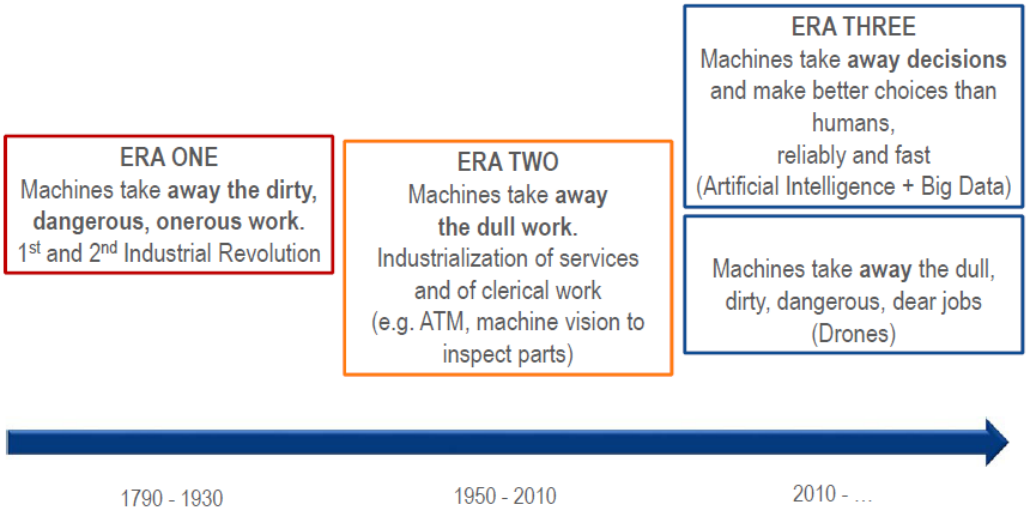


Figure 42 - The three eras of automation – source Neirotti

A widespread Culture of Safety can contribute to change the scenario, but data available are hard to read at a first glance, and an in-depth understanding requires expert analyst: first, it is necessary to make a distinction between Injuries and Health impairments.

The cultural effort matured with the enactment of the European Directives with the consequent passage from a rigid prescriptive approach to a flexible approach based on risk analysis, is therefore not sufficient to face such rapid technological development without "trauma" and the incessant and increasingly widespread reassignment of tasks within the companies.

In fact, although the European panorama is experiencing a profound change due to the advent of the Industry 4.0, the accident indices of the last few years do not seem to differ much from those typical of the 1970s even if, see Figure 43, the skill-biased technological change introduced a somehow different scenario: the demand for skilled workers has increased faster than its (surging) supply.

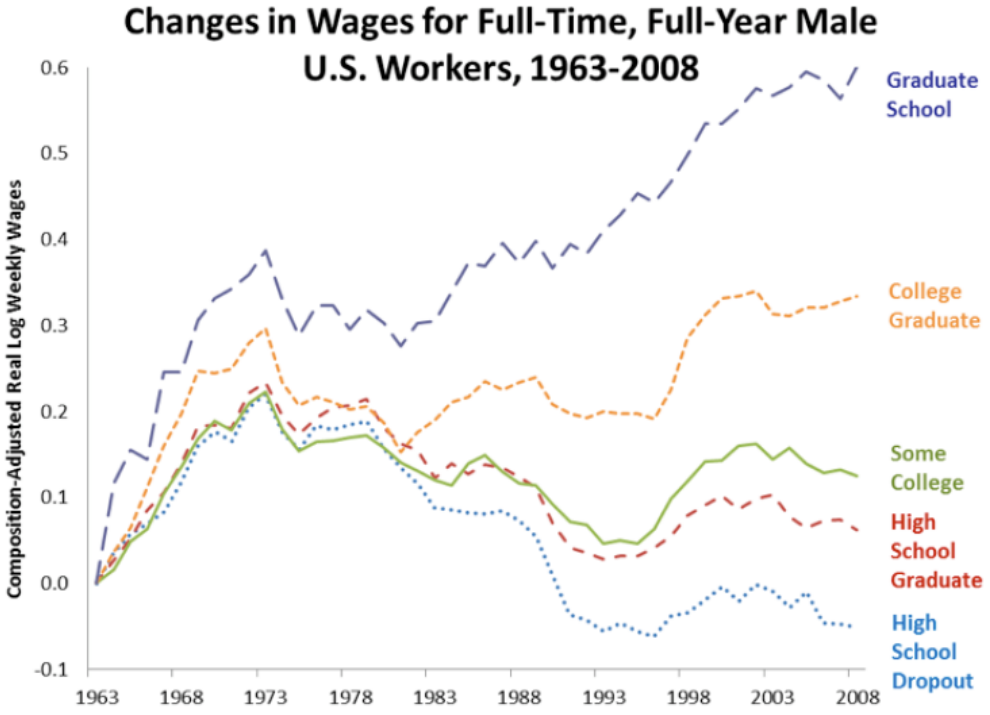


Figure 43 - The race between man and machine: Implications of technology for growth, factor shares and employment (Acemoglu & Restrepo, 2015)

This situation is nowadays influenced by factors connected to the distance between workforce general characteristic and the ever increasing workers' preparedness required, the power of new technologies, the aging of workforce and the connected inadequateness to work in particular fields. As shown in Figure 43, workers will be less and less involved in manual activities, and increasingly called to make complex decisions and to interact with technological tools: currently, it is necessary to face not only technological issues, but also organizational and cognitive ones.

Instead, the Inail statistics about the Health impairments are affected by other parameters and the situation at first glance seems to be totally overwhelmed: some pathologies totally or mostly disappeared or are under control, the etiology is well

known and consequently there is a related Regulation, which brought to a positive situation (e.g. the case of asbestos).

Meanwhile there are new pathologies rising in the last decades never heard before, or never considered as strictly connected to the Occupational activities, the use of new materials, new workplaces conception, different workload and robotics introduction.

The Eu OSHA forecasting is that in 2030, the 50 % of total occupational disease will be covered by stress connected pathologies, never considered during the last century data recording. Almost the same happened for the musculoskeletal disorders, the European Agency for Safety and Health at Work just in May 1998 launched a research information project on "*Work-Related Upper Limb Disorders (WRULD)*" to describe and assess these findings collecting relevant research results. The scope of the study included the demonstration of epidemiological evidence of connection to work, the dimensioning of the problem within Member States, the pathological basis for work causation and to demonstrate the effectiveness of work system changes[9].

Since then, for example, new tools aroused interest, making great strides, as wearable robotics.

These rigid suits and exoskeletons, adopted to increase the ergonomics of operations and reduce the incidence of occupational diseases due to excessive effort, or the adoption of incorrect postures prolonged over time, if widespread and correctly used can sensitively change again the scenario of exoskeletal work-related pathologies.

This example is a clear signal that a widespread Culture of Safety does not necessarily lead to a decrease in number of Health Impairments, but brings to a deeper consciousness of people involved in the OS&H field, finding the connection between emerging pathologies and work activities.

[9] A great deal of additional information on the European Union is available on the Internet. It can be accessed through the Europa server (http://europa.eu.int). Cataloguing data can be found at the end of this publication. Luxembourg: Office for Official Publications of the European Communities, 1999 - ISBN 92-828-8174-1 © European Agency for Safety and Health at Work, 1999 Reproduction is authorised provided the source is acknowledged. Printed in Belgium

6.2 How to face the problem

6.2.1 The innovation

Industrial revolutions have always led to evolutionary effects sometimes even disruptive to productivity. Resuming, we can affirm that:

- with the first Industrial Revolution technology has multiplied the force replacing physical human or animal strength;
- with the Second Revolution, technology multiplies the scale: electricity expands the size of markets and provides energy.
- the Third Revolution took place thanks to technologies that multiply speed: information could be processed and managed more quickly, and we had the introduction of robotics.

As shown in the following Figure 44, each revolution led to new schemes of organization that, in turn, had gained in efficiency and wealth, with a similar trend.

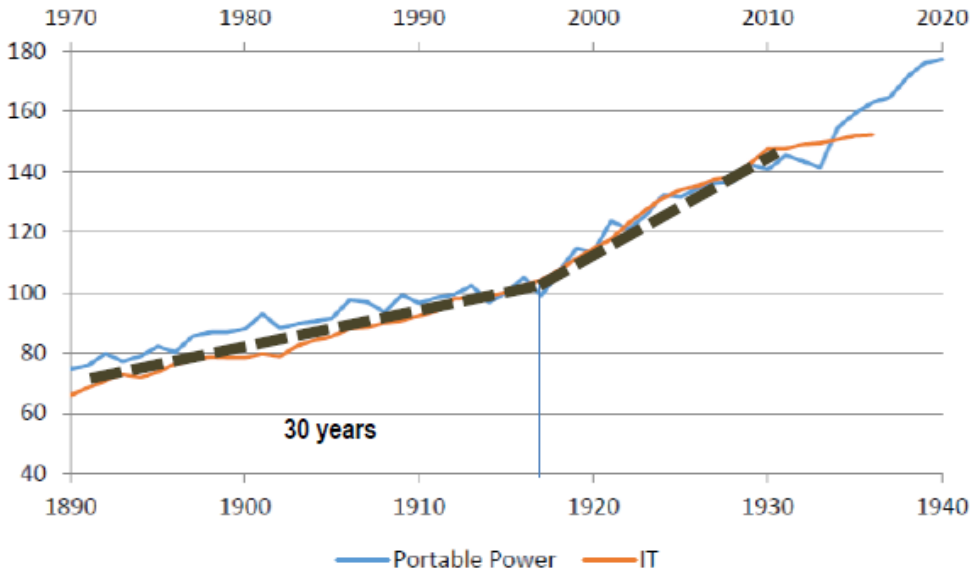


Figure 44 - Labor Productivity Growth in the Portable Power and Information Technology Eras – source Brynjolfsson et al, 2017.

In the last decades, the manufacturing ecosystem witnessed an unprecedented evolution of disruptive technologies forging new opportunities for manufacturing companies to cope with the ever-growing market pressure. The fourth industrial revolution, made possible by the availability of sensors and low-cost connections,

evolution of user friendly interfaces new materials, machines, components and automated systems, digitized and connected (Internet of Things and machines), and is associated with an increasingly pervasive use of information, computational technologies and data analysis. Of course, in an optic of the total automation of systems, the Safety would be higher thanks to the elimination of the Contact Factor: if the number of exposed is zeroed, the Risk is consequently inconsistent.

However, that would be effective in an ideal system, in the real-world practitioners know that the automation reduces the presence of humans, but does not reduce it to zero. Rather requires more specialized people able to make decision and to intervene in sensitive moments, as the need of maintenance or the stoppage of the System, moments of deviations, when is necessary to keep high the attention index.

Basically, we are facing a period of great innovation, the robotics are day by day more widely spread, but we don't have to forget that our Society is handling the so called IoT, acronym of Internet of Things, not Intelligence of Things. That means that technologies, when stimulated, answer following specific algorithms designed in laboratories, to the conceivable situations. It is important to keep in mind that technology is as safe as designers *taught* it to be.

Moreover, the race to create value for the customers has been hindered by several issues that both small and large Italian industrial companies have been facing, representing the driving force of changes such as shorter product life cycles, rapid time-to-market, product complexity, cost pressure, stimulate our exports to contrast the increased international competition, to contribute to the job demand and wealth and to the economic stability - financial and social cohesion.

In this scenario, people involved in OS&H should consider the content of digital technology application in manufacturing environment (Smart Manufacturing or Industry 4.0) from not only a political, but also an academic and industrial perspective. *More specifically, the challenges* in OS&H perspective *must be addressed when studying, driving and including digital innovation in products, processes and business models* (*Taisch, 2018*).

6.2.2 Regulations

"Good regulations promote innovations". From 2016 were enforced new laws concerning the incentives offered to push employers to innovate their factories changing the machineries, the integrated management systems to ensure Quality, Insurance and Sustainability, the ergonomic devices to improve the interaction and increase the Safety Conditions of the workplaces in vein with «4.0 Industry».

The integrated management system is for sure an element of potential improvement. Even years after the Roman Empire, it is still actual: European and National Regulation Bodies cited these models and, within the regulation of international standards on OS&H topics, recently enforced the UNI ISO 45001: 2018 "Management systems for Health and Safety at work - requirements for use".

The purpose of an OS&H management system is to provide a framework and a model for the general prevention as to provide and approach. Typically, a cyclic model is adopted (based on the Deming or PDCA cycle - Plan, Do, Check, Act) aimed at the continuous improvement of Health and Safety conditions in workplaces.

In this optic, it becomes necessary to consider The Culture of Safety an essential tool for the effective prevention in ethically and economically sustainable production systems. This approach should make people able to act aware to the OS&H spirit, logical before than regulated, and to avoid the passive approach of all the practitioners involved.

Even the National Plan of Prevention 2014-2018 brings *back the attention on* the issue of protection of Health and Safety in the workplace, adding the aspect of the social value of the existence of work, in addition to the ethical, institutional and normative importance.

It is clearly stated that the occurrence of accidents and work-related illnesses takes on an even wider social and economic value: tools to prevent accidents must be effective and synchronous with the legal and social background.

In addition, the changes in work conditions are surely modifying the approach with the Insurance Bodies: the Inail - National Institute for Insurance against Accidents at Work, is a non-economic public body that manages mandatory insurance against accidents at work and occupational diseases. The Insurance is mandatory for every worker, and the price for every worker is calculated on the basis of the statistics of the corresponding NACE Sector, the specific work

conditions of each Employer and, if any, the innovations implemented to eliminate or minimize the risks.

The Government push the employers to adopt innovations which already gave positive results in OS&H field, and on the same vein, also Inail promoted Campaigns of incentives to implement new and safer tools.

In parallel, a different unanswerable question is raising: in case of failure occurred in an automated system , who is the responsible? EU and member states reached a deep and clear Regulation for machineries available on the European market, but what are the differences in the 4th industrial revolution? Is the manufacturer responsible of the behavior of the robotics? If employer removes the barriers thanks to the capability of the robot to feel the presence of other workers, what happens in case of accident or unpredicted scenario? There is not a wide literature yet, there are some cases, for example in the testing of self-driving cars, the first victim occurred in March 2018 has gone viral, drawing the attention to the Responsibilities of the Company testing the vehicle. Wising avoiding any future civil litigation over the accident, the Company settled with family of the victim dodging the possibility of the courts to establish a legal precedent over liability in autonomous vehicle accidents.

Another similar episode happened in 2016 and *eight months after the fatal crash involving another Company's car operating in a computer-assisted mode, federal auto-Safety regulators said their investigation of the car found no defects in the system that caused the accident and said that Autopilot-enabled vehicles did not need to be recalled* (*NY Times, 2017*).

6.3 The research

The new directives created a chance for researchers and engineers to face a situation with innovative spirits, and the monetary incentives made available to the research centers started innovative process fast and effective, able to find solutions in a relative short time. In this regard, many issues worthy of attention are constantly submitted to working groups that operate in the Research Universities.

The role of scientific research is essential to contribute concretely to combine knowledge and technology and to c*reate awareness on Industry 4.0 topic to facilitate the understanding of the potentialities related to the new, smart and*

sustainable manufacturing of the future and to introduce the indispensable aspects of Occupational Health and Safety. Through a rigorous and dedicated analysis of the new working scenarios, as well as the dissemination of a Culture of Safety at all levels of the company, incentivizing a synergy "Industry-University" from a Safety point of view.

Research contributes *in spreading in a systematic and organic way the key elements enabling the new industrial revolution, from the new production technologies to the digital ones,* and has the duty to *provide concrete instruments to improve manufacturing processes efficiency and effectiveness, and Safety.* Through this process is possible to *"Create and consolidate multidisciplinary competences"*[10].

Although, it is important to make a distinction: Innovation 4.0 is not about introducing state-of-the-art machinery. The goal is to know how to combine different technologies to make an integrated factory, a system in which the production chain is a system connecting machines, people and information to create smarter products, smarter services and smarter work environments. The aimed transformation in key 4.0 would make possible to consider the workplaces as complex systems, networks that incorporate, integrate and put into communication machinery, plants and production facilities, logistics and data warehousing systems and distribution channels.

Through digital transformation and with the use of cyber-physical production systems, production should be able to quickly answer to the market demand, almost in real time, updating the product specifications, supply flows of raw materials optimizing the transformation processes, reducing errors and defects, improving *time to market* and ensuring flexibility, speed and precision.

The effects in terms of productivity recovery can be significant, restoring new competitiveness to productive sectors and manufacturing niches that otherwise

[10] SCorPiuS is supported by the European Union's H2020 Framework Program, under grant agreement nº 636906, European Roadmap for Cyber-Physical Systems in Manufacturing Vision and Gap Analysis

would have had serious difficulties in competing with low labor cost systems, in the best cases allowing re-shoring of delocalized activities .

Thus, the relationship between research and industry must be of collaboration and osmosis, even if research by its nature must try to look further, to prevent the future needs of companies. At the same time, it is of fundamental importance that the solutions developed in the research laboratories pervade the industrial reality, and do not get stuck just in laboratories or on scientific papers.

Safety could be improved through a better interaction and agility of man-machine system, that – also with the widespread use of remote control - would make possible a significant reduction of Contact Factor and - consequently – injuries. However, at the same time among the rising technologies, cooperative and collaborative robotics are playing a major role[11]. Modern robots are day by day more equipped with sensors that increase their awareness of the surrounding environment and they can identify the presence of people and respond accordingly. That was the key drive to reduce or eliminate the physical barriers traditionally used to delimit the operating space of a robot and to preserve the Safety of operators and workers. Therefore, the innovation paves the way to new workplace scenarios which multiply the possibilities of using robotics systems not only as an automation tool but also as a support to humans.[12]

Management becomes essential in the process and several small and medium-sized enterprises – SMEs – understood it and found internal solutions changing their organizational logic to be competitive.

A common answer is the Lean thinking is a new philosophy arisen in the 1990s as to support people development and continuous process improvement aimed at creating value and growth in the company to obtain more and more using less and less resources in the Toyota Production System and defined

[11] ISO 15066:2016 Robots and robotic devices -- Collaborative robots

[12] UNI EN ISO 10218:2011 Robot e attrezzature per robot - Requisiti di sicurezza per robot industriali

"Lean thinking" (*Womack et al., 1991*) to resume the concept of less human effort, less time, less space, less equipment and materials only after an in depth analysis and a continuous revision of the system.

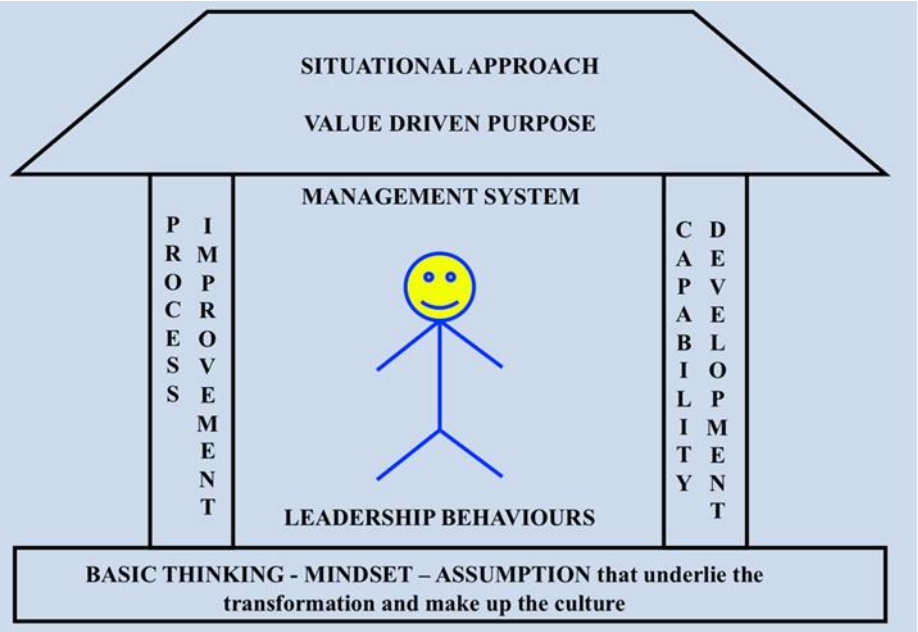


Figure 45 - the house of Lean

The three main topics are

1) to focus the problem to solve - as productivity increase, greater willingness to pay on the part of the customer or the reduction of operational and financial risks;

2) to improve the work identifying a set of methods, techniques and tools for the optimization of materials and information management activities within a productive context;

3) to develop people's full involvement to work within a framework of quality standards, principles, policies and guidelines, promoting training and capacity - building activities of the Organization (*Maida e Chiabert, 2018*).

The third point highlights that the new idea of Production systems should support and assist operators in carrying out their duties lead to a reduction in work-related stress, and to the overcoming of some limits in terms of the availability of personnel already adequately trained, the aging of the workforce, the integration of workers with disability, etc.

Nevertheless, other *evergreen issues are* the working spaces conditions, the wear and obsolescence, failure mends and vandalism. The role of working spaces in workers' Safety is often underestimated and reduced to swallow building inspection, maybe using prefilled checklists. Research, innovations and Advanced criteria driven from forensic canvassing are sketched to achieve a formalized and systemic full analysis, customized on each room of a wide compass of building heritage and construction systems where work takes place, revealing and recording any incompliance to properly manage workers' S&H.

6.3.1 Innovation and Great Works

As said, New technologies implementation in infrastructural and great works are also important not only for the final intended use, "*but also as real technical and technological challenges, and a moment of development and evolution of the whole national system during the years, and across all phases from design to execution*."

In fact, in pilot-tunnels' construction sites introduced various innovative tools are being introduced, even experimental ones, to test technical innovations available in the market, and be ready and aware to choose the one perfectly fitting the needs of the Company for the main tunnel.

One of the cornerstone of Industry 4.0 revolution is the Communication, which is, at the same time, a criticality in infrastructural and great works – even worse in underground yards.

One of the first step in Industry 4.0 was to introduce wifi connection along tunnels making easier the communication and allowing workers to save time in the management of the various operations held at the simultaneously.

The introduction of the network in the construction sites was the first step even to place sensors that enabled the designers to describe the functional volumes involved in the different operations, helped by ad hoc developed software useful to be more efficient and concurrently increasing the Safety level of workers in reduced space as a Tunnel (Figure 46).

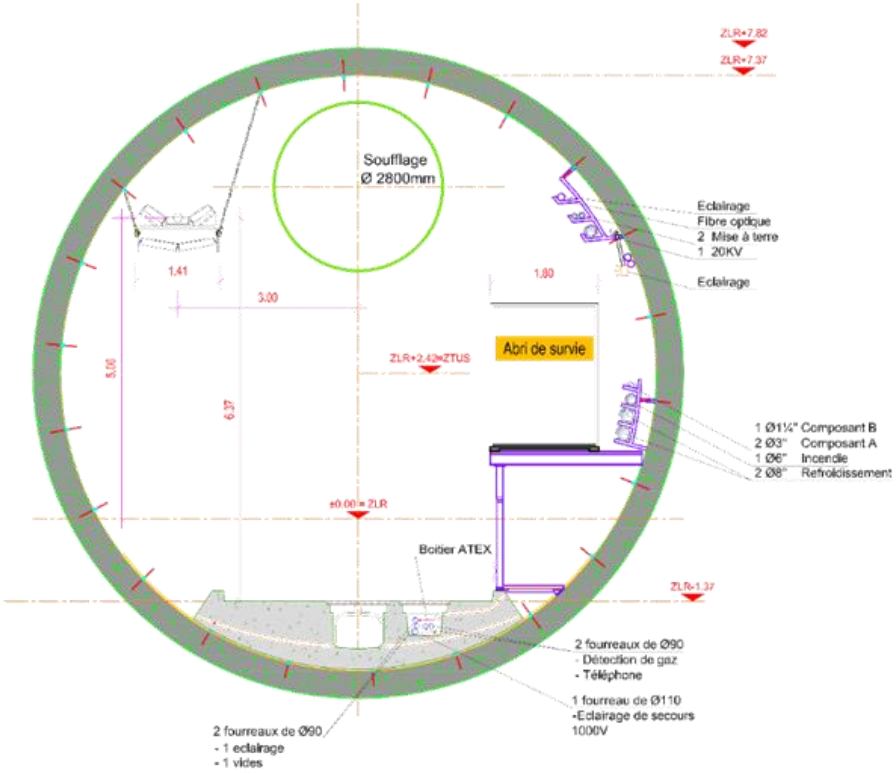


Figure 46 - pilot tunnel Lyon-Turin - diameter 11 253 mm

Other innovations consist in the use of sensors applied on vehicles and on the path they are supposed to run across: an example already widespread in Industry is represented by the qualitative leap of automation systems supporting factory logistics, the Automatic Guided Vehicles (AGVs)[13]. They are commonly used to move materials around a manufacturing facility or warehouse, following markers or wires in the floor, or using vision, magnets, or lasers for navigation and designed to autonomously avoid collisions with humans or obstacles. In the Underground works, typically characterized by limited areas and compresence of a multitude of vehicles, designers have implemented the "Système de guidage des TSP" from the experimentation to the perfection and completion of the System as described in the following Figures 47 an Table 35[14]. Facing peculiar construction sites, is hard that manufacturers design up a machinery (even if responding to the Regulation requirements) or a system that perfectly fits with the needs of every yard.

[13] Tesi di laurea in Tecniche della Prevenzione nell'Ambiente e nei Luoghi di Lavoro: *Reasoned analysis of management optimization measures at the plant of a primary firm. Discussion of automation results of internal transport systems*, a.a. 2015-2016, candidato: Federico Tendi, relatori: M.Patrucco, E.De Cillis, L.Maida.

[14] Ing. Gianluca Comin Ingenieur Travaux TBM Spie Batignolles Genie Civil

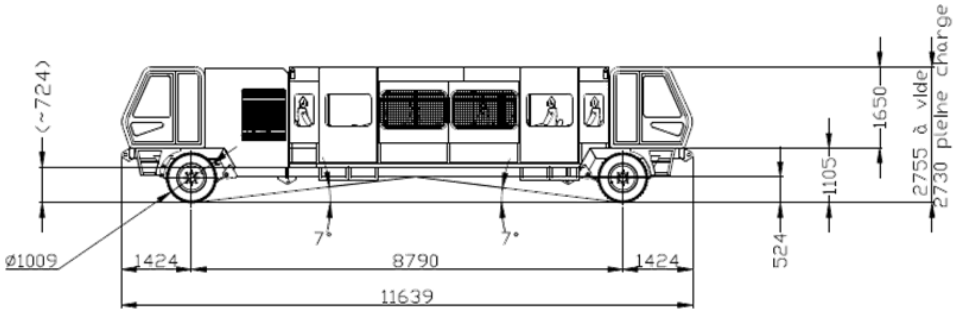
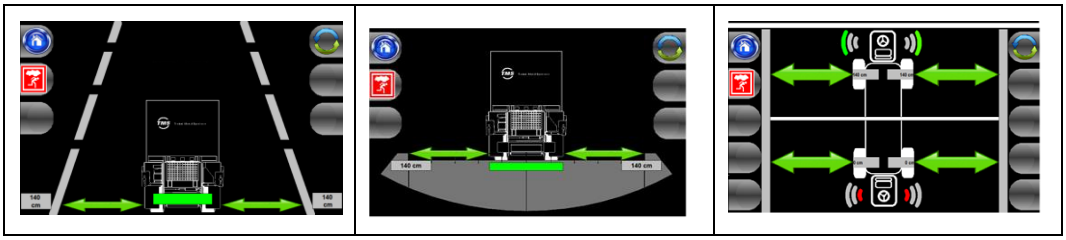


Figure 47 - description and measures of the TSP

In this case the TSP was updated and designers made it work in a tunnel.

Table 35- screenshots of control system on TPS



Thus, the role of designers and practitioners involved in these kind of great works, is not only to select the fitting technology and put it in operation, but also to assess the characteristics of machinery and yard and find solutions to make them work properly and, if needed, to test them for a while and eventually propose improvements or changes.

6.3.2 Deviations

It's important to bring the attention on the possible deviations in the system, causing Safety problems; the more in case of emergencies. That is the reason why workers operating with such a complex system have to be specialized and ready to promptly react and manage the emergence with a grade of freedom in the decision making process. Designers and head of projects don't are always available to give answers to raising problems and, as in the case of fire or similar emergencies, people involved should be able to communicate and react to break the chain of events as quickly as possible. However, in many High Risk NACE Sectors, the workers are heterogeneous, the decision making process is not clear and, above all, not always they are not aware of their duties and responsibilities in OS&H matters. In many

cases, they do not even talk a common language, so that, when a deviation occurs, a series of misunderstandings can lead to a situation of emergence.

The Operating Procedure must help the operator make decisions quickly, safely, efficiently and perform actions that are highly likely to succeed (*Lees, 2004*). In fact, when needed, the operator would not have time to read the procedure and understand it, so it is necessary that they have been informed, formed and trained before starting working, the procedure must be clear and effective to allow operators to act immediately.

A key information, a constant, already announced in the literature, is the importance of a timely alarm and the training of workers involved, ready to sudden intervene in the emergency management.

Since it is not always possible to practice simulation - implying work stoppage, involving all the workers and the possible introduction of hazards in complex workplaces, the new technologies can be of great help: it is nowadays possible to use simulators, augmented reality, assisted systems to simulate an emergency and to learn how to react in a short time span. There also systems able to reproduce fire situation kept under control but used to train the emergency bodies introducing all the factors contributing in such kind of situations (fog, heat, noise..).

Another way to be ready to face an Emergency is the use of engineering models, designed to give an idea of the possible scenarios connected to the known parameters considered, also if even this methodology is not free from contradictions. For example, considering the fire Safety system/plant designer is seldom the same person responsible of the Risk Analysis; the consequence is often a poor coherence between the Safety documents and the actual project result. Moreover, some lack of clarity can rise up on the techniques used for the Hazard quantification, the most serious problem concerning the input data adopted for the computing models, and their quality (*Borchiellini, 2016*).

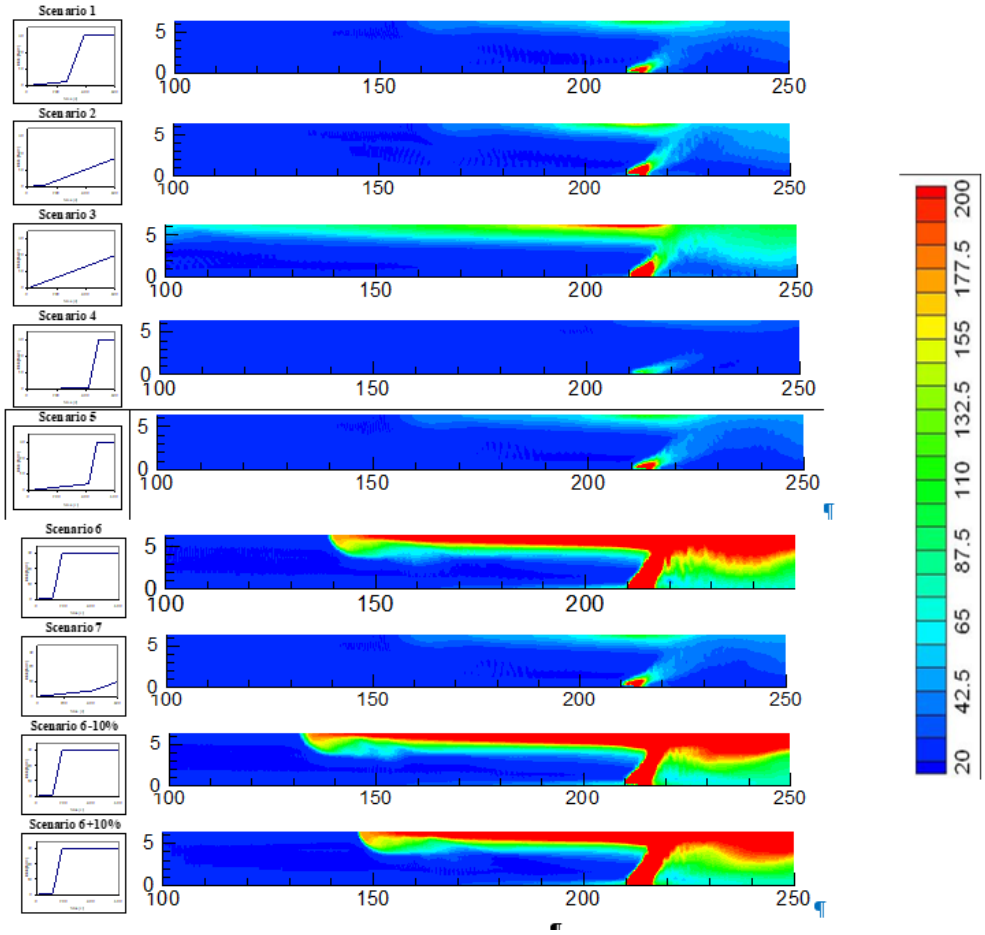


Figure 48 - - differences in the results attainable by changing the profile of the HRR curve

But the following question is: what's the level of confidence of reality described by models?

The new multi-scale model brings to a large reduction of the computational time with practically no significant effects on the simulation results, but what is the grade of description of it?

The great challenge is therefore to define models and procedures able to identify the confidence interval of the results obtained from the models used for the Safety analysis in case of emergency.

To enforce the Legislative decree 264/2006 concerning the emergency management & the Safety training, it is nowadays to make the representation of events more and more effective through Virtual Reality, useful as part of assessment of the emergency plan and the implementation of Safety exercises and training of personnel who must operate in these situations.

6.4 In closing

I4.0 deals with innovative topics, from a technical-technological point of view, from the point of view of human resources and their characteristics and management in a productive reality subject to substantial changes, and finally also from the point of view of the important changes that such modifications may entail, in particular with regards to the Occupational Safety and Health , also on liability profiles, and regulatory and insurance aspects.

Many of these issues are in strict connection with the study and research topics of the Education of workforce, although the vastness of the field and the multidisciplinary aspects of the dissemination of the culture of Safety make stimulating to confront qualified skills in the various sectors.

Chapter 7

Discussion & Conclusion

Too often, it is necessary to accept *a posteriori* the dramatic consequences of improvised approaches to prevention, due to proposals not resulting from a thorough study, lacking of Culture of Safety, constant updating and a hint of modesty, obsolete beliefs that only consider the result of the project, and not the Safety of people charged of the implementation, even neglecting the basics of the Safety Regulations and Standards.

As seen in the above described cases, errors often are attributable to the still widespread inability of old school decision makers to understand the consequences of technological choices that inevitably will lead, past the long latency times, to irreparable consequences on workers' Health. Moreover, the rigid entrenchment behind the stock phrase "you work to produce, not to improve Safety", whose interpretation of convenience can lead to an objectionable distribution between profit of some, and loss of others.

This thesis aim was to contribute to a change of Socio-Cultural perspective, putting in the core the Safety of every link of the chain, every human being involved, trying to decontextualize the victims from the work dynamics: the Universal Declaration of Human Rights (*UDHR, 1948*), a milestone document in our history, sets out for the first time the fundamental human right to be universally protected, embracing people with different legal and cultural backgrounds from all regions of the world. It can seem trivial, but the first aim of this thesis is to protect people, disseminating the Culture of Safety, informing workers about their rights and educating employers on their responsibilities under the Occupational Safety and Health Act. This work is not necessarily addressed to experts in OS&H, it would be addressed to workers, citizens, politicians, spouses or parents in order to create a society of aware people, not only in terms of OS&H regulations, but especially in human and labor rights relations insofar as it lies within their power.

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Appendix A

Worker Survey

Instructions:

Thank you for participating in our study. Below are some questions regarding Safety, your employer, and your work environment. **Mark** the response that best answers the question as it relates to the contractor you are working with today. **Do not write your name on this survey.** Your responses will be kept confidential.

Section 1

→What is the name of the **general contractor** you are working for today?

[_____]

These questions refer to the site you are currently working on and your *general contractor*.

	On my current site…	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	The general contractor uses any available information to improve existing Safety rules.	☐1	☐2	☐3	☐4	☐5
2	The general contractor tries to continually improve Safety levels in each department.	☐1	☐2	☐3	☐4	☐5
3	The general contractor listens carefully to our ideas about improving Safety.	☐1	☐2	☐3	☐4	☐5
4	The general contractor reacts quickly to solve the problem when told about Safety concerns.	☐1	☐2	☐3	☐4	☐5

→What is the name of the **subcontractor** you are working for today? [_____]

These questions refer to the *subcontractor* you are working for today.

	With my current subcontractor…	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
5	Unsafe working conditions are identified and improved promptly.	☐1	☐2	☐3	☐4	☐5
6	Equipment is well maintained.	☐1	☐2	☐3	☐4	☐5
7	Action is taken when Safety rules are broken.	☐1	☐2	☐3	☐4	☐5
8	Job hazard analyses are frequently performed with me.	☐1	☐2	☐3	☐4	☐5
9	Time and money are spent on improving Safety.	☐1	☐2	☐3	☐4	☐5

Think about your experiences with your *current* foreman or immediate supervisor on this job site.

	My foreman/supervisor…	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
10	Compliments employees who pay special attention to Safety.	☐1	☐2	☐3	☐4	☐5
11	Frequently talks about Safety issues throughout the work week.	☐1	☐2	☐3	☐4	☐5
12	Discusses with us how to improve Safety.	☐1	☐2	☐3	☐4	☐5
13	Uses explanations (not just compliance) to get us to act safely.	☐1	☐2	☐3	☐4	☐5
14	Is strict about working safely even when we are tired or stressed.	☐1	☐2	☐3	☐4	☐5
15	Refuses to ignore Safety rules when work falls behind schedule.	☐1	☐2	☐3	☐4	☐5

Think about how you and your foreman or immediate supervisor communicate about Safety.

		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
16	I try to avoid talking about Safety issues with my foreman/supervisor.	☐1	☐2	☐3	☐4	☐5
17	I feel that my foreman/supervisor openly accepts ideas for improving Safety.	☐1	☐2	☐3	☐4	☐5
18	I am reluctant to discuss Safety-related problems with my foreman/supervisor.	☐1	☐2	☐3	☐4	☐5
19	I feel that my foreman/supervisor encourages open communication about Safety.	☐1	☐2	☐3	☐4	☐5

The following questions refer to how you feel about Safety and your Safety knowledge.

	Today…	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
20	I feel that it is worthwhile to put in effort to maintain or improve my personal Safety.	☐1	☐2	☐3	☐4	☐5
21	I feel it is important to maintain Safety at all times.	☐1	☐2	☐3	☐4	☐5
22	I believe that it is important to reduce the risk of accidents and incidents in the workplace.	☐1	☐2	☐3	☐4	☐5
23	I know how to perform my job in a safe manner.	☐1	☐2	☐3	☐4	☐5
24	I know how to maintain or improve workplace Health and Safety.	☐1	☐2	☐3	☐4	☐5
25	I know who to report a hazard to when I see one on the job.	☐1	☐2	☐3	☐4	☐5

These questions refer to the Safety rules on your current site.

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree

26	**I carry out my work in a safe manner.**	☐1	☐2	☐3	☐4	☐5
27	**I use all the necessary Safety equipment to do my job.**	☐1	☐2	☐3	☐4	☐5
28	**I use the correct Safety procedures for carrying out my job.**	☐1	☐2	☐3	☐4	☐5
29	**I ensure the highest levels of Safety when I carry out my job.**	☐1	☐2	☐3	☐4	☐5
30	**I promote the Safety program within the organization.**	☐1	☐2	☐3	☐4	☐5
31	**I put in extra effort to improve the Safety of the workplace.**	☐1	☐2	☐3	☐4	☐5
32	**I help my co-workers when they are working under risky or hazardous conditions.**	☐1	☐2	☐3	☐4	☐5
33	**I voluntarily carry out tasks or activities that help to improve workplace Safety.**	☐1	☐2	☐3	☐4	☐5

Think about what happens when someone is <u>injured</u>.

	With my current subcontractor…	**Strongly disagree**	**Disagree**	**Neither agree nor disagree**	**Agree**	**Strongly agree**
34	**Someone from the company contacts the worker shortly after an injury or illness to express concern and offer assistance.**	☐1	☐2	☐3	☐4	☐5
35	**The company keeps track of the injured worker's absence and return to work.**	☐1	☐2	☐3	☐4	☐5
36	**The company works with the treating physician to develop a plan for return to work.**	☐1	☐2	☐3	☐4	☐5
37	**The company makes accommodations such as special equipment, flexible hours or modified job duties to allow injured worker to return to work.**	☐1	☐2	☐3	☐4	☐5
38	**After the injured worker returns to work, the company follows up to adjust the work situation as needed.**	☐1	☐2	☐3	☐4	☐5
39	**When injured workers can't return to their job, the company provides retraining.**	☐1	☐2	☐3	☐4	☐5

These questions refer to your <u>Safety training.</u>

		Strongly disagree	**Disagree**	**Neither agree nor disagree**	**Agree**	**Strongly agree**
40	**I feel like I receive adequate Safety training to do my work.**	☐1	☐2	☐3	☐4	☐5
41	**What I learn from Safety training is useful when doing work.**	☐1	☐2	☐3	☐4	☐5

42	I use the information I learn from the training on work sites to a great extent.	☐1	☐2	☐3	☐4	☐5
43	My Safety skills have improved as a result of training.	☐1	☐2	☐3	☐4	☐5
44	I feel like I have enough resources to do my job safely.	☐1	☐2	☐3	☐4	☐5

Section 2

The following questions also refer to your Safety training.

45. What type of Safety training have you received?(Check all that apply)

☐1 **OSHA 10 training**
☐2 **OSHA 30 training**
☐3 **HAZMAT training**
☐4 **Safety orientation upon arrival on a new site**
☐5 **Other (Please specify):_____**
☐6 **None**

46. How frequently do you receive site specific Safety training upon your arrival at a new site?

☐1 **Never**
☐2 **Rarely**
☐3 **Sometimes**
☐4 **Often**
☐5 **Almost Always**

The following questions refer to injuries you may have experienced.

47. In the past 12 months, did you experience injuries at work?

☐1 **Yes**
☐2 **No → Skip to Question 55 (Section 3, pg. 7)**

48. Please describe the injuries that you experienced (i.e., cut finger, broken arm, sprained ankle).

_____
_____
_____
_____

49. Did you tell your supervisor about any of these injuries?

☐1 **Yes**
☐2 **No**

50. What happened after these work injuries? (Check all that apply)

☐1 **I received first aid treatment**
☐2 **I saw a nurse**
☐3 **I saw a doctor**
☐4 **I was prescribed prescription medication**

☐5 I went on light duty or restricted work (assigned different work tasks)
☐6 I missed one or more days from work
☐7 None of the above

51. Did this injury occur on this site?

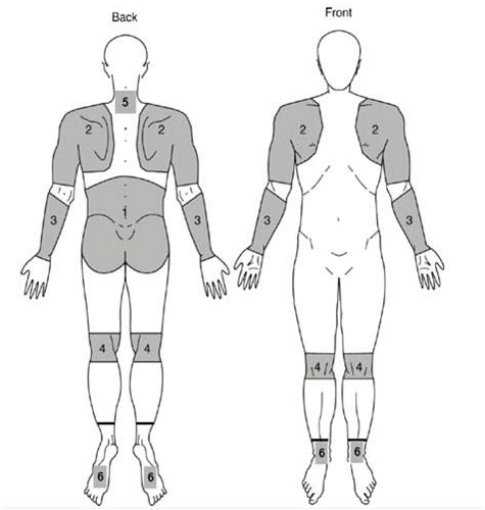
☐1 Yes
☐2 No

52. The following questions refer to injuries that occurred *within the last 4 weeks*. Circle the number that best describes any pain/discomfort you have experienced in the following body parts in the last 4 weeks:

	Body Part	No discomfort							Extreme discomfort
a.	Low Back	0	1	2	3	4	5	6	7
b.	Neck or Shoulders	0	1	2	3	4	5	6	7
c.	Arms or hands	0	1	2	3	4	5	6	7
d.	Legs (hips, knees, feet, ankles)	0	1	2	3	4	5	6	7

53. During the past 3 months, have you had pain or aching in any of the areas shown on the diagram? *Choose as many of these as apply to you:*

☐1 Lower back (Area 1)
☐2 Shoulder (Area 2)
☐3 Wrist or forearm (Area 3)
☐4 Knee (Area 4)
☐5 Neck (Area 5)
☐6 Ankle or feet (Area 6)
☐7 None of the above



54. In general, how much did this pain (in any body area) interfere with your normal work?

☐1 Extremely
☐2 Quite a bit
☐3 Moderately
☐4 A little bit
☐5 Not at all

Section 3

55. Please rate the severity of the following symptoms that you may have had in the past week.

		None	Mild	Moderate	Severe	Extreme
a.	Pain in the lower back	☐1	☐2	☐3	☐4	☐5

b.	Arm, shoulder, or hand pain	☐1	☐2	☐3	☐4	☐5
c.	Neck pain	☐1	☐2	☐3	☐4	☐5
d.	Tingling (pins and needles) in my arm, shoulder, or hand	☐1	☐2	☐3	☐4	☐5
e.	Pain in my legs or knees	☐1	☐2	☐3	☐4	☐5
f.	Pain in my feet	☐1	☐2	☐3	☐4	☐5

Please enter the following demographic information.

56. **Age (years) [____]**

57. **Gender**

☐1 **Male**
☐2 **Female**
☐3 **Other identity**

58. **Race/ethnicity (Select one or more)**
☐1 **Hispanic or Latino**
☐2 **White**
☐3 **Black or African American**
☐4 **Native Hawaiian or other Pacific Islander**
☐5 **Asian**
☐6 **American Indian or Alaska Native**
☐7 **Other (specify)_____**

59. **What is your trade? (ex: carpenter, pipefitter, etc.)**

[_____]

60. **Please list the name of the subcontractor that you are working for <u>today:</u>**

[_____]

61. **Are you a union member?**

☐1 **Yes**
☐2 **No**
What is your local? [_____]

62. **How long have you worked for your current subcontractor?**

[___] Years
[___] Months

63. **What is your position on your current project?**
☐1 **Foreman**
☐2 **Apprentice crew worker**
☐3 **Journeyman crew member**
☐4 **Other (specify):_____**

64. **Who is your *primary* employer?**
☐1 **The general contractor**
☐2 **The subcontractor**
☐3 **The Union**
☐4 **Other (specify)_____**

65. **Who pays you directly?**
☐1 **The general contractor**
☐2 **The subcontractor**
☐3 **The Union**
☐4 **Staffing agency**
☐5 **Other (specify)_____**

66. Have you ever taken this exact survey before today?
☐1 **Yes**
☐2 **No**

----------Thank you for completing the survey!----------

[i] https://www.inail.it/cs/internet/home.html