RISK ASSESSMENT IN MAINTENANCE ACTIVITIES: A SPECIALIZED METHODOLOGY THROUGH A SIMPLIFIED APPROACH

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Maintenance is not a sector, but it is a high-risk activity carried out in all sectors and all workplaces. The European Union Occupational and Health Administration (EU-OSHA) maintenance activities were recognized as being the riskiest jobs performed among the conventional ones. The figures and major accidents show that 10 to 15 % of all fatal accidents at work and 15 to 20 % of all accidents are connected with maintenance [1,2], the main causes being the maintenance works special characteristics as analyzed in the following as well as the difficulty of employing an effective integrated approach within the already existing Health & Safety Management Systems [3].

Managing workplace incidents, which actually is translated to preventing them at a level as low as reasonably practical (ALARP), starts with planning which in turn includes a Risk Assessment of the activities under review. This is the first stage of the problem Safety Professionals encounter. There is no specific Risk Assessment methodology, not even as a framework, that could be as detailed as appropriate for activities so complex, diverse and specific entailing such a rich combination of simultaneous risks. The existing methodologies are either too simple to cover the maintenance jobs or too complicated to be implemented or continually updated by the maintenance personnel itself once the Safety Professional or Consultant delivers the Risk Assessment Study [4,5].

This paper presents a methodology that has been gradually developed and resolved these issues in practice and is currently being implemented in mainly high-hazard industries where maintenance works are mostly conducted in-house and include mostly high risk tasks.

Additionally, in spite of the fact that the reader of this paper may be quite knowledgeable on the Risk Assessment methodologies, the author presents his case by including a first stage where the principal terms used in a Risk Assessment Study are clarified, their correlation explained and the Risk Assessment methodology analytically depicted since even in this area there is still much ambiguity. At this stage also useful tools are cited for the Safety Professionals' facilitation, use and, why not, improvement.

Risk Assessment Methodology

Abbreviations

RA : Risk Assessment

RAS : Risk Assessment Study

MAs : Maintenance Activities

H&S : Health & Safety

PIS : Probable Incident Scenario

ALARP : As Low As Reasonably Practical/ Possible

PPE : Personal Protective Equipment

JSA : Job Safety Analysis

EU-OSHA : European Union Occupational H&S Association

STF : slips, trips, falls

Terminology & Tools Library

Even in the most recent editions of the standards governing the H&S requirements, the terminology does not seem to be consistent [6,7,8]. In other H&S professional editions popular among the H&S professionals the same inconsistency appears [9,10]. Therefore, for the purposes of this paper the following terminology is adopted, which is also used by the author when conducting RAS's. The whole approach needs to be linked to the business objectives of achieving their goals by reducing the probability of loss.

Maintenance Actyivities : A broader term to denote the extent and diversity of maintenance works

Affected Party : Any employee, visitor, contractor or bystander present during an Organization's activity

Loss: Any non-recurring removal of, or decrease in, an asset or resource hence, in H&S terms, directly linked to the consequences of an incident.

Incident Scenario: a foreseen undesirable event that could result in a more or less severe accident or occupational disease which, in turn, results in an affected party's psychosomatic health degradation.

Probable Incident Scenario : an incident scenario foreseen by the Organization or its Risk Assessor's that may result in loss.

Hazard or Hazard Source : Anything that has the potential of causing an incident to the employees (object, substance, tool, machinery, equipment, installation, situation, work, behaviour etc.).

Danger : The property that makes a hazard dangerous (slipperiness, speed, sharpness, reactivity, intensity, voltage, height difference, weight, tension, temperature, carelessness etc.) when used during an activity.

Incident : The interaction (contact/ exposure) of an employee to danger (fall, contact with hot surfaces, exposure to noise, impact with moving objects etc.).

Consequence/ Hazard Effect : The form of employee health degradation (fracture, burn, bruising, shock,

loss of consciousness, irritation etc.).

Risk : The combined probability (uncertainty) for an incident scenario to happen during an activity, based on the following parameters:

The incident scenario's health consequences severity, without taking into account any existing or recommended measures

The frequency of exposure to the activity's dangers

The likelihood of the probable incident scenario taking into account the existing measures with respect to the full range of measures that must be implemented

Necessary clarifications are presented on the difference among Hazard Source – Danger – Risk:

A hazard source has a natural substance (tangible or intangible) therefore it always exists.

The danger appears when the hazard is used therefore it exists only during an operational activity.

The risk however expresses the combined probability for an incident to happen during the operational activity and therefore it depends on the effectiveness of the implemented measures.

Necessary clarifications are presented on the difference between Risk– Likelihood:

Risk (and therefore the risk index in a RAS) expresses the level of probability of an incident to occur during a specific operation taking additionally into account the operational (job/ task) conditions i.e. the frequency of employee exposure, the incident scenario severity, the number of employees affected etc. The variation of this

Likelihood (and therefore the likelihood index in a RAS) expresses the level of probability of an incident to occur during a specific operation due to the lack of H&S measures implementation.

In the following tables with lists of the RA parameters are presented that could to be used as data libraries for the H&S Risk Assessors.

Hazard Source List	
Floors	Loads
Hot/ cold objects	Confined Spaces
Chemicals	Low density materials
Machinery	Pests, animals, rodents
(Tools (hand, power	Microorganisms
Equipment	Microclimate
(.Network lines (cabling, piping, ducts etc	Workplace organization
Installations	(Work organization (psychosocial
Structural installations	Combustibles + ignition sources
Vehicles	Behaviour

Table 1: Hazard Source list (the underlined hazard sources may also cause occupational diseases)

Danger List		
Slipperiness	Poor visibility	Low density
Obstruction of movement	Radiation	Poor illumination
Height difference	Electrical voltage	Air draught
Temperature extremes	Asphyxiating atmosphere (lack of 02/ toxic substanc-(es presence	Vibration
Reactivity		Sedentary/ static work
Movement/ Inertia	Humidity	Monotony
(Sharpness (edge/ point	Insufficient ventilation	Stressfulness
Particle release	Infectiousness	Intensiveness
(Tension (belt/ spring		Storage height
Weight		Center of gravity position
Pressure		
Vacuum		
Noise		

Table 2: Danger list (the underlined dangers may also cause occupational diseases)

Probable Incident Scenarios (PIS) List	
(Slipping at (& falling at/ to/ from	Inhalation of chemicals
Tripping/ stumbling at (& falling at/ to/ (from	Swallowing of objects/ chemicals
Bumping/ knocking/ hitting into/ against (protruding) objects/ surfaces at the same level	Exposure to biohazards
Hit/ struck/ crushed by falling/ moving objects	Fire
Falling from another level	Explosion
Contact with elements under voltage	Entrapment/ asphyxiation by low density/ asphyxiant materials
Contact of the skin/ eyes with sharp/ pointed objects	Overexertion
Contact of the skin/ eyes with hot/ cold surfaces/ chemicals	Exposure to adverse working environment ((microclimate, physicochemical agents
	Working under adverse psychosocial environment

Table 3: Probable Incident Scenarios list (the underlined PIS may also cause occupational diseases)

The Risk Assessment Study (RAS)

The RAS methodology used in most industrial applications is more demanding regarding its analysis. The 5-step process proposed by EU-OSHA proved to be insufficient in practice, except for very low risk Organizations. The author has successfully implemented a more detailed 10-step approach which was gradually improved and depicted in Figure 1 below; on the right-hand side, the corresponding involved parties' involvement is depicted in which the importance of the Organization's contribution at the 7 first stages is apparent as, no matter how knowledgeable a H&S Expert may be, the specific Organizational input RA data must be provide by the Organization whose Affected Parties are more familiar with their everyday tasks.

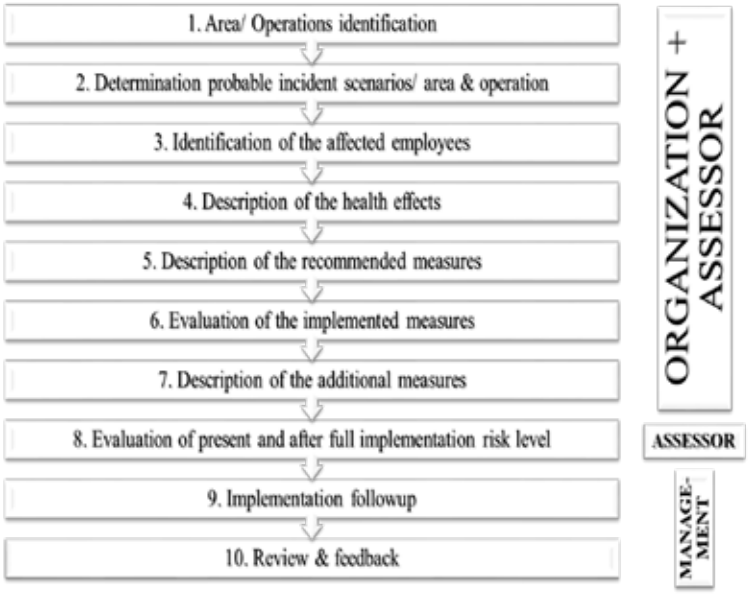


Figure 1: The improved 10-step Risk Assessment Study approach that must be used for industrial and other high-risk operations

Since the objective of a RAS is to identify the broadest possible range of applicable measures so as to minimize risk to an ALARP level, a table of the categories of H&S measures usually applied is presented in Table 4.

H&S Measures List
1. Legislation
2. Specifications
3. H&S Management System (Procedures/ Guidelines/ Work In-(structions/ Safe Methods of Work
4. PPE
5. Communication Tech-niques (Training, Meetings, Promo-(tional Activities
6. Signage
7. Safety Equipment
8. Measurements

Table 4: H&S Measures list to be more analytically specified as an output of the RAS

The above tools, presented in Tables 1-4, are absolutely necessary to assist the Risk Assessor so as to conduct a RAS as complete as possible for any kind of activity, irrespective of the complexity degree; the methodology that this Risk Assessor must implement with the aid of the above tools is shown in Figure 2 below.

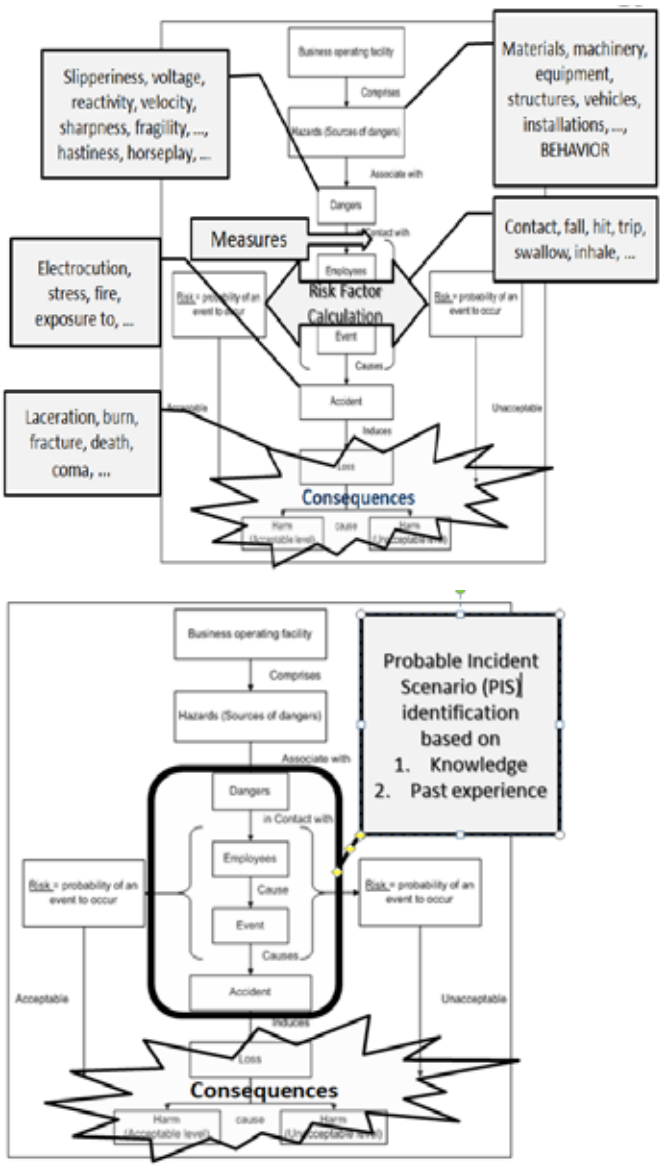


Figure 2: The RA methodology flowchart: (Left) Implementation presentation with the support of the tools presented and, (Right) the stage where the identification of Probable Incidents Scenarios takes place in order to specify the necessary measures

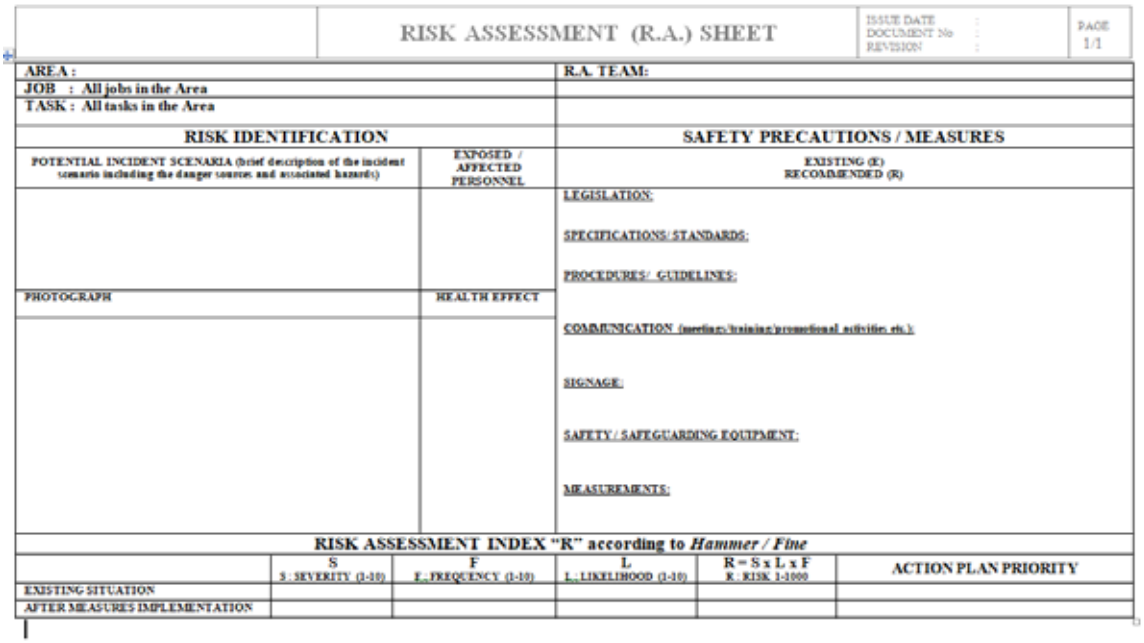
Figure 2 will not be analyzed as this is beyond the scope of this paper, but it is presented in order to depict the correlation of all the above tools presented (left) as well as to depict the fact that the key factor of any RAS is to identify and present to the maximum possible extent the Probable Incident Scenarios (PIS's) in order for the Organization to be able to list the complete set of appropriate measures that reduce the risk to ALARP levels and therefore:

evaluate the existing measures

recommend, if necessary, existing measures upgrade

recommend additional measures

Practically, all the above information can easily be combined in one RAS sheet form (Figure 3) as developed by the author and being used for years now with absolute success in thousands of RAS's.



RISK ASSESSMENT (R.A.) SHEET		ISSUE DATE DOCUMENT No REVISION	PAGE 1/1
AREA : JOB : All jobs in the Area TASK : All tasks in the Area		R.A. TEAM:	
RISK IDENTIFICATION		SAFETY PRECAUTIONS / MEASURES	
POTENTIAL INCIDENT SCENARIA (brief description of the incident scenario including the danger sources and associated hazards)	EXPOSED / AFFECTED PERSONNEL	EXISTING (E) RECOMMENDED (R)	
		LEGISLATION: SPECIFICATIONS/ STANDARDS: PROCEDURES/ GUIDELINES:	
PHOTOGRAPH	HEALTH EFFECT		
		COMMUNICATION (meetings/training/promotional activities etc.): SIGNAGE: SAFETY / SAFEGUARDING EQUIPMENT: MEASUREMENTS:	

RISK ASSESSMENT INDEX "R" according to *Hammer / Fine*					
	S S: SEVERITY (1-10)	F F: FREQUENCY (1-10)	L L: LIKELIHOOD (1-10)	R = S x L x F R: RISK 1-1000	ACTION PLAN PRIORITY
EXISTING SITUATION					
AFTER MEASURES IMPLEMENTATION					

Figure 3: An one-page RAS sheet form that contains all information based on the PIS's identified by the Risk Assessor

In this sense, the list of PIS's presented in Table 3 is quite important as we shall see in the second part of this paper.

The Risk Assessment Methodology in Maintenance Activities

The second part of this paper goes further to analyze the requirements of an effective RAS for maintenance activities. The Risk Assessors must never forget that the RAS end-users are the members of the Affected Parties. The RAS objective is to identify the PIS's in order to specify the measures that the Affected Parties must use. Consequently, a RAS must be a tool that can be easily understood, implemented, improved and even updated by all levels of the Organization's Affected Parties which in this case is the Maintenance Personnel.

This part analyzes the special nature of maintenance activities to conclude why the methodology presented in the first part above, although comprehensive, is quite insufficient. On the other hand, a very comprehensive RAS would be extremely voluminous thus making it hard to be further managed not only by maintenance personnel but by the H&S Risk Assessors or H&S Professionals themselves. So, this part presents a simplified RAS methodology for maintenance activities which is as analytical as possible but

also, easy to be compiled, used and updated by the Affected Parties.

At this point it must be noted that this methodology does not rely on theoretical data; the author's consultancy team, comprising experienced scientists, has implemented this simplified methodology in the heavy industry with great success the driver being the fact that an Organization may be willing or legally imposed upon to conduct a comprehensive RAS, but the budget usually presents the most serious burden. So, this simplified approach not only provides a practically manageable methodology in practice but this means that the time savings on behalf of the Risk Assessor and the resulting financial savings on behalf of the Organization, leads to a win-win situation.

The Maintenance Activities special characteristics

Maintenance activities are characterized by a number of specificities linked mainly to (a) the maintenanceActivities and, (b) maintenance personnel mentality. More specifically:

Maintenance activities are characterized by:

Lack of housekeeping (disassembling, laying out tools, occupying floor space, handling liquids etc.) leading to high STF hazards, the most common incident cause in every activity

Mentally & physically demanding activities (manual handling, extreme caution etc.) leading to fatigue and high stress situations

Specialized knowhow (for managing electrical, hydraulic, pressurized etc. systems)

Task diversity & complexity (to manage risk combinations under insufficient work methods) leading to high-focus demand in turn leading to high stress levels and H&S rules violation due to insufficient training

Repeated tasks (especially when conducting preventive maintenance) leading to familiarization with danger the most common basic cause of accidents leading to trivial mistakes in case any situation deviates from normal

"Non-productive" work (time pressure to complete the required tasks) leading to stress, H&S rules violation and mistakes

Maintenance personnel:

Are required to move and work in all areas of the Organization even outside the premises (to purchase materials and/ or equipment or even to execute maintenance tasks e.g. in company vehicles)

Execute tasks in almost all installations & equipment

Bear the belief that since they are usually highly skilled, they possess the knowhow to execute their work safely

Maintenance activities are also exposed to a combination of risks that are:

Area-related since maintenance personnel are present in most areas (workstation risks, non-working area risks like confined spaces, roofs etc., outdoor areas, off-site areas)

Job/ task-related (for tasks that may be regular, but also may be non-regular, or very rare tasks requiring specialized knowhow)

Work-related (since they are exposed to all kinds of hazardous energy types like thermal, radiation, kinetic, noise as well as unsafe behaviors and psychosocial hazards due to stress)

Maintenance activities are usually not risk assessed as they are not part of the normal operation activities and in that sense are somewhat "invisible". Moreover, and owing to the above, a RAS is quite a cumbersome task for H&S Risk Assessors that demands specialized knowhow, a lot of paperwork and meticulous approach making the deliverables difficult to produce, extremely time-consuming and, moreover, expensive, an issue that cannot be easily justified to the Organization's Management that usually do not possess the knowledge or rather the expertise to understand or justify such a high cost.

Furthermore, as mentioned above and as it is going to be analyzed below, the RAS becomes unmanageable due to complexity and volume thus being rendered useless and, finally, inert.

Maintenance Activities in phases

Maintenance activities are only considered the ones that are related to the maintenance coreActivities at the machinery and equipment under the scope of work, but actually that is only around a portion of the job. Maintenance activities can be expanded into three phases:

Phase 1: Preparation → Infrastructure works management

Target group (machinery, equipment, building, installations etc.)

Procedures, guidelines review

Hardware (tools, chemicals, PPE, LOTOTO, spare parts etc.) selection

Maintenance area preparation (evacuation, traffic control, signage etc.)

Maintenance target (machinery, equipment, installation, building etc.)

Phase 2: Execution → "Core" maintenance works

Procedures, guidelines implementation

Power supply management → LOTOTO, Confined space entry

Hardware use for repair → Hand & power tools, Devices

Repair, replacement of worn parts

Disassembly, reassembly → Special tasks

Phase 3: Delivery → Trial runs, commissioning, restoration

Procedures, guidelines implementation

Hardware use

Commissioning (test/ trial runs)

Area & object restoration (housekeeping, waste management)

Delivery to users

The Maintenance Activities Risk Assessment Methodology Process

From the above analysis, any H&S Expert realizes that in order for an effective RAS to be conducted (namely identify all the PIS's for all MAs conducted in an Organization) requires an analysis as detailed as possible. In Figure 4, the author presents the RAS Process stages depending on how detailed the risk analysis must be.

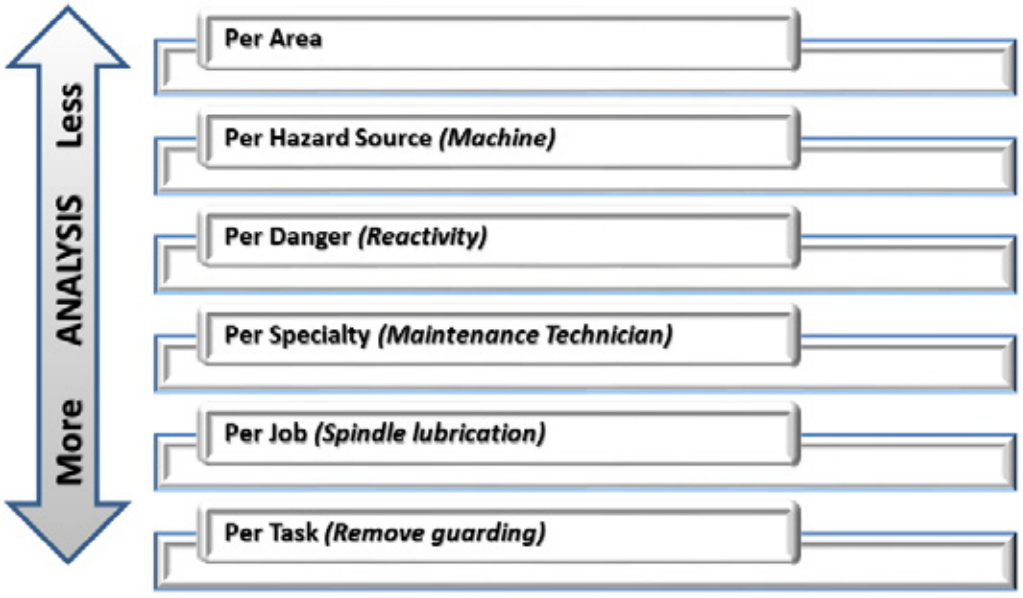


Figure 4: A representation of a RAS stages depending on how detailed the risk analysis is required to be depending on the operation under examination (in parenthesis examples related to MAs)

It is obvious that a RAS for MAs must be as detailed as possible in order to achieve identification of as many PIS's as possible which in turn means that a RAS must comprise a JSA as anything less would be insufficient.

Maintenance Activities Job Safety Analysis (MAs JSA)

Before proceeding we must again cite some definitions that will be taken in to account in the MAs JSA:

The expert knowledge required to effectively execute a duty comprises a specialty.

A set of duties necessary to effectively execute one or more jobs comprises a job position.

A set of similar tasks comprise a job or duty.

The issue

Having conducted a number of RAS's for MAs, the author and his team of H&S Expert Risk Assessors concluded that the following data are more or less accurate within a statistical error:

Average number of maintenance specialties/ Organization = 3

Average number of PIS's/ maintenance specialty = 15 (out of total 17 see Table 3)

Average number of jobs assigned to a maintenance specialty = 20

Average number of tasks in a job = 15

Hence, if we assume that we use one single RAS sheet (see Figure 3) to describe and manage the information of one PIS, the total number of RAS sheets required would result from the multiplication of the above numbers resulting in 13500 RAS sheets, this number being just an average. It is clear that a new approach is necessary.

The line of thinking

MAs RAS must specify preventive measures for all tasks performed; however, maintenance job tasks are more than 1000 in most industry operations. However, the PIS's could be described in a limited number (maximum 17).

In most cases, some PIS's are already identified during the previous RAS Stages (see Figure 4) and need not be repeated for each task. Therefore, one can develop a RAS per PIS which would include all applicable job tasks of each specialty excluding the scenarios already identified in the previous stages of more General RAS's that have usually already being conducted. That means that the improved 10-step RAS approach depicted in Figure 1 must be adapted so that the PIS's are allocated to each job task, while the rest of the process remains unaltered. Nevertheless, since most H&S Experts do not possess the knowhow to list the MAs and then further analyze them into jobs and each job into tasks as it is required, it is absolutely necessary that the Maintenance Department contributes in the early stages of the RAS process to provide this data.

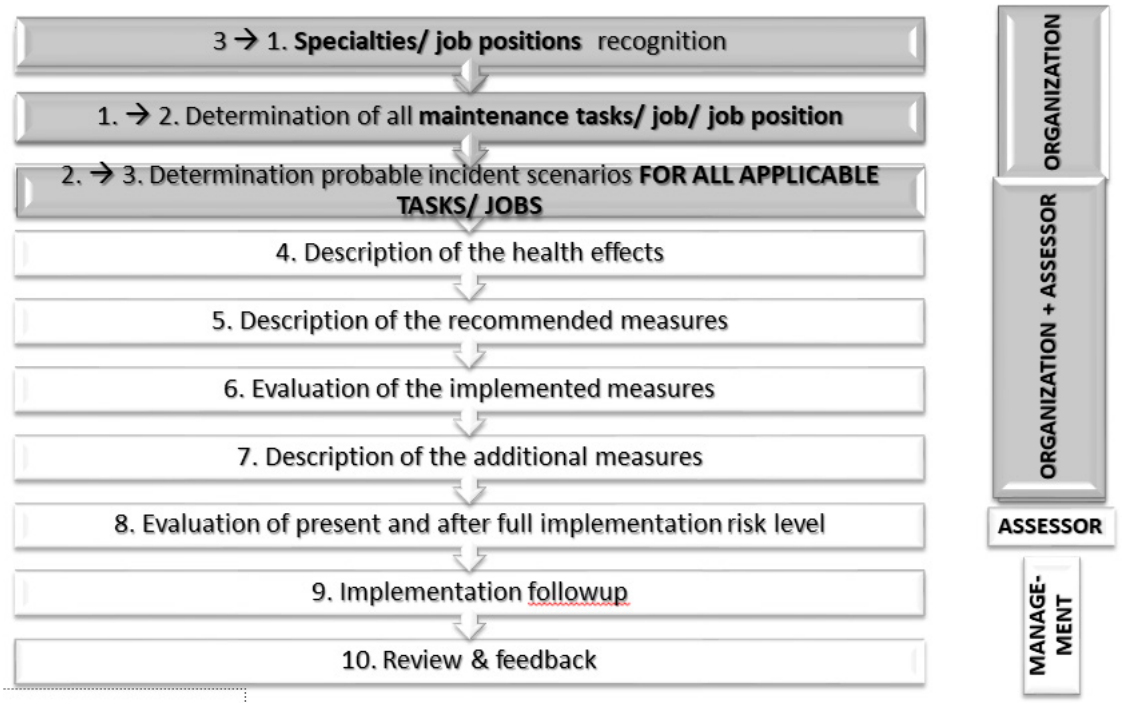


Figure 5: The improved 10-step Risk Assessment Study approach that must be used for industrial and other high-risk operations adapted for MAs; the changes with respect to Figure 1 is noted in grey

The simplified methodology to conduct a Maintenance Activities Job Safety Analysis (MAs JSA)

This new RAS methodology requires at first that the degree of involvement of the Organization is absolutely necessary in the first 3 steps during which the H&S Risk Assessor must guide Maintenance Personnel to provide him/ her with lists of the maintenance specialties e.g. electrician, machine shop mechanic, welder etc. and then provide for each specialty a list of jobs they perform and further on break down each of these jobs into tasks.

For example, an electrician may perform jobs like electrical motor testing, electrical panel thermographic inspections, lighting fixtures replacements, electrical equipment repairs etc. These jobs in big companies are usually described in the Job Description Sheets and could also be provided to the H&S Risk Assessor by the Human Resources Department, but they still have to be checked and verified by the Maintenance Organization (Manager or Supervisor).

If the Organization decides to conduct a full JSA, then again the Maintenance Organization must provide a full analysis of each of the jobs into a list of tasks taking into account all the maintenance job phases as described in paragraph 3.2 above.

For example, to execute a thermographic inspection job the electrician needs to prepare a program for the panel under consideration, review the H&S guidelines (since this inspection is conducted under full load and when the circuits are live), prepare the PPE that must be used (insulated gloves, safety glasses etc.), prepare the demarcation equipment (electrical hazard signs, cones etc.), evacuate the immediate

electrical panel area, open the panel door, remove the front electrical panel cover, apply full load, take the thermal imaging picture, replace the panel cover and so on.

Then, instead of examining each and every job or task to assign all PIS's the following procedure is made by the H&S Risk Assessor:

They assess which of the PIS's are applicable (for MAs this number is 15 on average/ job, see 4.1 above)

They record ONLY ONCE the PIS's that are applicable for all jobs of the specialty; for example, if the MAs are executed in areas with noise, then the PIS "exposure to higher than the permissible noise levels" (number 16 in the PIS list of Table 3) is only recorded once for all jobs and tasks and need not be repeated. These PIS's are linked to the Organization's infrastructure and are probably included in the general Area RAS, so a simple reference or reproduction is sufficient and saves time. In any case, one or two RAS sheets are sufficient to cover these PIS's.

Then, they record ONLY ONCE the PIS's that are applicable for all MAs (jobs or tasks or both); for example if the job involves maintenance of a food filling line during which maintenance personnel walks on a wet floor, then the PIS "slipping at and falling exposure to higher than the permissible noise levels" (number 1 in the PIS list of Table 3) is only recorded once for all jobs and tasks and need not be repeated. In this case also, one or two RAS sheets are sufficient to cover these PIS's.

Then, they assign all applicable tasks to each REMAINING PIS's, since the above already analyzed PIS's need not be repeated. In practice this step rarely results in more than 10-12 RAS sheets.

The overall result is a RAS document for each job that has an average of 15 RAS sheets and covers all tasks for each job, i.e. it comprises a JSA for the MAs under assessment.

The above RAS process analysis approach creates the need to change the general RAS sheet form presented in Figure 3 to include additional data for each maintenance job or task. More specifically, it is necessary to include fields where the Organization will list all the jobs per job position and/ or all the tasks per job for the detailed RA analysis. These RAS forms correspond to the fulfillment of the first two steps of the MAs RA process shown in Figure 5 and must be filled, as already mentioned, by the Maintenance Professionals (Director, Manager, Technician etc.) of the Organization. This form is presented in Figure 6.

	JOB POSITION (SPECIALTY) RISK ASSESSMENT STUDY PER JOB			Page 1 / 19
JOB-POSITION:			ASSESSORS :	
JOB-POSITION STEP-ANALYSIS INTO JOBS (Duties): 1. 2. 3. 4. 5. 6. 7. 8. 9. 10.		11. 12. 13. 14. 15. 16. 17. 18. 19. 20.		

Job Serial No.	HAZARD SOURCE/ DANGER / PROBABLE INCIDENT SCENARIO (PIS)	HEALTH CONSEQUENCES	H&S CORRECTIVE MEASURES EXISTING (E) / RECOMMENDED (R)	RISK FACTOR BEFORE S	F	L	AFTER S	F	L
IN			*See the General RAS*						
O			*Conduct a General RAS applicable for ALL Jobs*						
List of all applicable jobs per Probable Incident Scenario			*Conduct a RAS per the remaining Probable Incident Scenarios*						

Figure 6: The initial form the Maintenance Professionals must fill and deliver to the H&S Risk Assessor for the latter to initiate the MAs JSA

The next step is to be able to present the RAS data in a manner as concise as possible without sacrificing the required detail, according to the procedure described above (steps 1-4). For this purpose the RAS form is slightly changed as depicted in Figure 7 below.

	JOB POSITION (SPECIALTY) RISK ASSESSMENT STUDY PER JOB	Issue Date : Document No. : Revision :	Page 2 / 20

Job Serial No.	HAZARD SOURCE/ DANGER / PROBABLE INCIDENT SCENARIO (PIS)	HEALTH CONSEQUENCES	H&S CORRECTIVE MEASURES EXISTING (E) / RECOMMENDED (R)	RISK FACTOR					
				BEFORE			AFTER		
				S	F	L	S	F	L
IN ***or*** **O** ***or*** **List of all applicable Jobs per PIS** *(e.g. 2,4,6, 9,13, 15)*	**PIS No. X** [e.g. PIS No.1 SLIPPING AT (& FALLING FROM/TO)]	*Example for PIS No1:* • Death • Coma • Concussion • Fracture • Dislocation • Swelling • Bruising	**Legislation** **Specifications** **H&S Procedures/ guidelines** **Communications** **Signage** **Safety Hardware (PPE, safety equipment)** **Measurements** **Additional guidelines**						
IN : The risk concerns the installation/ premises/ area infrastructure **O : The risk concerns ALL jobs performed by the job position**			**S : SEVERITY (1-10) L : LIKELIHOOD (1-10) F : FREQUENCY (1-10)** **R : RISK FACTOR (SxLxF=1-1000)**						

Figure 7: An one-page RAS sheet to conduct the MAs JSA

The H&S Risk Assessor needs to examine the list of jobs of the form depicted in Figure 5 and then examine the PIS's applicable for the jobs listed and start allocating jobs to the PIS's and not vice versa, as follows.

The not applicable PIS's are excluded (e.g. replacing electrical fixtures may not involve exposure to biohazards i.e. PIS 11 on Table 3). From the remaining PIS's:

If a PIS is caused by the Organization's infrastructure (e.g. exposure to workplace noise due to the machinery operation in the production area during the MAs performed) then this is indicated as "IN" in the first column "Job Serial No." and need not be analyzed further since it is already included in the more general versions of the RAS.

If a PIS is MAs-specific and concerns ALL the jobs of the job position i.e. jobs 1-20 in the list of form of Figure 6 (e.g. slipping due to a slippery floor in the production area) then this is indicated as "O" in the first column "Job Serial No." and it is only analyzed once for the job position.

Then, to the remaining PIS's the applicable jobs are assigned in the first column "Job Serial No."; for example for the job of changing lighting fixtures, PIS No.5 from Table 3 "Falling from another level" is applicable only for the jobs of the list of Table 6 that involve the use of ladders, scaffolds, elevated platforms, scissor lifts etc. so in this column these serial numbers shall simultaneously be assigned (e.g. 2,4,6,9,13,15) and will not be repeated for each job or task, thus saving additional RAS sheets (in this example 1 RAS instead of 6 only for the PIS no.5 of falling from another level).

The volume reduction **is** further achieved if we consider the fact that:

infrastructure PIS's (IN) could be mentioned in the MAs JSA but need not be further analyzed, but only referenced to the less analytical RAS

more than one descriptions of a specific PIS may be described in the

more than one PIS's may be analyzed in the RAS sheet of Figure 7

In Figure 8 that follows, one actual example is presented, extracted from a MAs JSA conducted for a heavy metal forming industry. All identification data were removed for obvious reasons.

	RISK ASSESSMENT STUDY PER JOB	Issue Date : Document No. : Revision :	Page 1 / 13
SPECIALTY: Maintenance		**ASSESSORS :**	

JOB ANALYSIS:

1. Contact with the Production Supervisor (for the machinery working status)
2. Contact with the Machine Operators (for malfunctions)
3. Daily visual machinery inspection
4. Machine failures Repair & Maintenance
5. Semesterly maintenance of all machinery
6. Working at heights
7. Forklift operation
8. Overhead crane operation
9. Grinding machine operation
10. Machine-tool operation (boring)
11. Machine-tool operation (lathe, drill, mill)
12. Diesel engine basic maintenance
13. Hand pallet truck operation
14. Air-conditioning filter change
15. Cooperation with electricians (e.g. when repairing a motor)
16. Visiting the warehouse to get chemicals
17. Use of chemicals on chillers and the production machines
18. Roller conveyor cleaning
19. Welding
20. Repair and maintenance of pressurized air and hydraulic systems
21. Use of pressurized air
22. Office work – Computer usage
23. Contacting suppliers
24. SAP use
25. Contacting machine shops
26. Contractor supervision
27. Visiting all plant areas
28. Moving to and from the working area

Task Serial No.	HAZARD SOURCE/ DANGER / POTENTIAL INCIDENT SCENARIO	HEALTH CONSEQUENCES	H&S CORRECTIVE MEASURES EXISTING (E) / RECOMMENDED (R)	RISK FACTOR BEFORE S	F	L	AFTER S	F	L
IN	Exposure to Voltage Exposure to Noise Slipping, Tripping, Falling from Stairs Slipping, Tripping, Falling on the Floor		*See General Area Risk Assessment*						
O	Fire Overhead weights Manual handling Ergonomic Infectious agents								

	RISK ASSESSMENT STUDY PER JOB	Issue Date : Document No. : Revision :	Page 3 / 13

Task Serial No.	HAZARD SOURCE/ DANGER / PROBABLE INCIDENT SCENARIO	HEALTH CONSEQUENCES	H&S CORRECTIVE MEASURES EXISTING (E) / RECOMMENDED (R)	RISK FACTOR BEFORE S	F	L	AFTER S	F	L
IN	**SLIPPERINESS** • Slipping and falling on the floor and potentially fall on hard surfaces, due to - Chemical spillage - Metal welding residues - Lubricants spillage - Cleaning agents/ water - Tools on the floor - Metal machine-tools residues - On-the-floor loose temporary cabling - Slippery material transferred on the Safety Shoe soles - Materials placed on the floor (e.g. packaging materials)	• Fracture • Concussion • Sprain • Strain • Contusion • Cut • Brazing	**EM** General Housekeeping Rules **EM** Housekeeping procedures/ guidelines **EM** General Safety Rules training **EM** Use of anti-slip safety shoes **RM** Industrial vacuum cleaner **RM** Emergency Spill Kits including Disposal EquiPMent **RM** Industrial vacuum cleaner **RM** Anti-slip floor material **EM** Regular floor cleaning **RM** Do not abandon spare parts, loose cables, tools and other objects on the floor	8	5	5	8	4	4
				200			128		
O	**INFECTIOUS AGENTS** • Infection due to poor personal hygiene • Possible contact with rodents, reptiles, insects • Illness due to travel to foreign countries	• Death • Come • Poisoning • Infection • Contusion • Abrasion • Illness	**EM** Annual pest control program **EM** Annual examination by an Occupational Physician **RM** The consumption of F&B is strictly prohibited in the working areas **RM** All personnel must follow high hygiene standards **RM** All F&B Must be consumed and refreshed daily **RM** All personnel travelling abroad should be informed and follow the	10	4	4	10	3	3
				160			90		

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				BEFORE			AFTER		
				S	F	L	S	F	L
				9	5	5	9	5	4
3 5 7 11 12 16 17 18 20	**REACTIVITY** • Inhalation of fumes or skin contact (cleaning agents, lubricants, solvents): - During equiRMent and machinery R&M - During spare part surface cleaning, degreasing - During the use of adhesives - Because of probable chemical spillage - Due to violating safety rules • Inhalation of fugitive emissions during sand/ glass blasting in case of extraction system failure or during the feeding of the sand to the sand blaster • Exposure (inhalation, skin, eye) to welding fumes • Exposure (inhalation) to airborne particles (dust, trimmings, flings) during material cutting, brazing	• Irritation (skin, eye) • Burn • Poisoning • Respiratory problems • Loss of consciousness • Long-term health effects	**Legislation / specifications** **EM** Chemical agents safe handing **EM** CLP/ GHS **EM** SDS **EM** Health Program **Procedures/ guidelines** **RM** Safe chemical handing/ storage **RM** Spill control emergency procedures **PM** Spill control equiRMent **RM** Training **RM** Health Examinations for Fit-to-the Job Certificates **Communications** **RM** Chemical safety cards **RM** Toolbox Talks **RM** Chemical Substances Committee meetings **RM** Safety Chemicals Handing Booklet **Signage** **EM** Π02-Π09, Y04, Y09-Y12, Y18, Y19, A02, A23, A25 **RM** Chemicals Posters, Incompatibility Charts **RM** Posting of Chemical Safety Cards **Safety Hardware** **RM** Safety glasses/ goggles, Safety gloves, Respirators, Dust Mask, Full-face/ Half-face Masks, Welding Mask **EM** First Aid Kit **RM** Industrial vacuum cleaner **RM** Emergency Spill Kits including Disposal EquiRMent **EM** Eye wash/ Safety shower **RM** Hazardous chemical cabinets **Measurements** **RM** Airborne agents measurements **RM** Dust measurements **General Guidelines** **EM** Smoking and naked flames are prohibited **EM** Jewelry is prohibited **EM** Eating and drinking are prohibited **EM** Use only approved containers with the appropriate labels	225			180		

Figure 8: Example of a set of RAS sheets for MAs JSA

The updating process

The RAS JSA forms used in this MAs JSA are of general form and can thus be used for other activities as well. Moreover, their setup facilitates the updating process by either the H&S Risk Assessors as well as the Maintenance Professionals. This updating may be executed quite easily in 3 steps,

If a job/ task is added, removed, changed then one can:

- Change the job/ task list
- Add to/ remove from the first column the corresponding number of the task
- Update the data only in the applicable fields
- If a recommended measure is complied with then one can:
- Change the prefix from RM (recommended measure0 to EM (existing measure)
- Recalculate the risk factor under the column "AFTER"

Results

The results of this approach in order to conduct a Risk Assessment Study of Maintenance Activities as analytical as to result in a Job Safety Analysis as analytical as possible and put it in a manageable form easily to be updated, had impressive results.

The number of Risk Assessment Study Sheets to conduct a Job Safety Analysis for Maintenance Activities was reduced from the expected 13500 if the conventional methodology were used to only around 400 for heavy industries with mainly in-house maintenance and employing around 1000 employees.

The number of working hours allocated was reduced by 250-300 per Study resulting in substantial fee savings on behalf of the Organization but, on the other hand, making the H&S consultancy fee tendering

more competitive on behalf of the H&S Consultant.

After 3-4 years of implementation the Maintenance Personnel as well as the internal H&S Professionals seemed quite satisfied by the RAS completeness and manageability.

Conclusions

Maintenance activities are so complex that, in order for a Risk Assessment Study (RAS) to be complete and effective, it should be conducted per Task or Job meaning that only a Job Safety Analysis (JSA) is acceptable, which in turn demands excessive resources if conducted with the conventional methodologies.

The JSA methodology can be simplified if the safety expert takes into account that, instead of conducting a RAS per Task, they can instead conduct a RAS per Probable Incident Scenario excluding the ones already covered by more general versions of the RAS.

The presented methodology achieves all the above objectives not only in theory but also in practice, as it was tested in very demanding high-risk industrial environments

The achieved volume as well as time savings may reach 80% thus making the RAS/ JSA easier to conduct as well as more manageable by the Organization.

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