Integrating Risk Management and Prevention through Design (PtD) Standards

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Introduction

ANSI/ASSE Z690.2-2011 (ISO 31000) can be applied to an entire organization, as well as specific processes, activities or projects. (ANSI/ASSE/ISO, nd; ISO, nd). Risk management process involves applying logical and systematic methods for communication and consultation throughout the process, identifying, analyzing, evaluating and treating risk associated with any activity, process, function, project, product, service or asset, monitoring and reviewing risk; and recording and reporting the results appropriately.

Prevention through Design (PtD) addresses occupational safety and health needs in the design and redesign processes to prevent or minimize the work-related hazards and risks associated with the construction, manufacture, use, maintenance, and disposal of facilities, materials, equipment, and the service sector. One of the goals is to educate designers, engineers, machinery and equipment manufacturers, SH&E professionals, business leaders, and workers to understand and implement PtD methods and apply this knowledge and skills to the design and re-design of new and existing facilities, processes, equipment, tools, and organization of work.

ANSI/ASSE Z690.2-2011 (ISO 31000) includes three main sections: Risk Management Principles (Clause 3); Framework (Clause 4), and Process (Clause 5). ISO 31000 (ANSI/ASSE Z690.2-2011) is not one of the incorporated standards in ANSI/ASSE Z590.3 -2011, the PtD standard. (ANSI/ASSE, 2011). However, SH&E professional could play a significant role in incorporating PtD principles into the risk management process. PtD principles could be successfully integrated into ISO 31000 Clause 5. Clause 5 (Process) is one of the key sections of the Risk Management standard. A key component of the Process is Risk Assessment (Section 5.4). According to the standard, Risk Assessment is an overall process of risk identification, risk analysis and risk evaluation. The authors see a direct link between the two standards. Section 7 of the PtD standard details the hazard analysis and the risk assessment process. Furthermore, both standards provide guidance on risk assessment techniques. The authors strongly believe that the PtD standard should be incorporated in ISO 31000 Clause 5. Suggestions for ANSI/ASSE Z690.2-2011 (ISO 31000) and ANSI/ASSE Z590.3 -2011 integration are presented below.

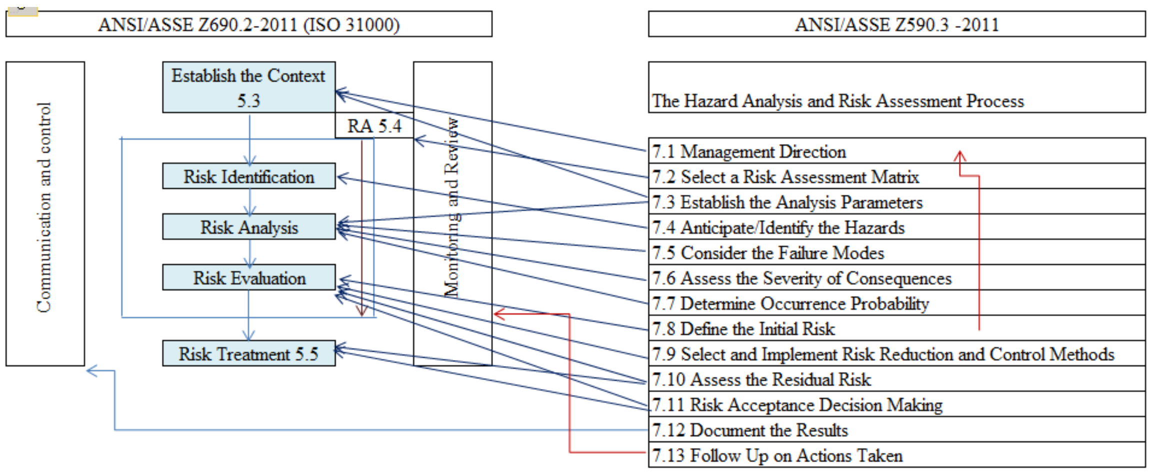

Fig.1. Possible ANSI/ASSE Z690.2-2011 (ISO 31000) and ANSI/ASSE Z590.3 -2011 integration suggestions.

The authors believe that the initial risk, PtD Section 7.8, should be discussed before the selection of risk assessment matrix.

SH&E professionals should learn how to develop tools and models to incorporate appropriate hazard identification and risk assessment techniques into the risk management process. The authors developed new tools based on the recommended risk assessment techniques referenced in both standards. Risk assessment tools were successfully utilized to demonstrate effective risk assessment methodology for a new product development.

Project Description

SH&E professionals are facing increased pressure to diversify their skills and develop new risk assessment techniques. A small size company requested a new product risk assessment and hazard evaluation. Their products are intended for export to the European Union. Therefore, it had to meet the requirements set forth in ISO standards. On the other hand, the product is manufactured in the USA and the management wanted to implement PtD principles. The authors developed new tools and successfully implemented the new PtD model to evaluate the product. The model allows different solutions to be evaluated and prioritized. The Excel-based tool helped the SH&E professionals and a student team that assisted the authors to compare PtD based design to an existing product that was not developed according to PtD principles. To satisfy the new product expectations and gain support for SH&E improvements, the team had to develop a new PtD based risk assessment methodology.

The purpose of this project was to determine the noise levels, hand and arm vibration risk, and potential particulate matter exposure from a normal production unit. The risk assessment evaluation included sound level meter, hand and arm vibration instruments and particulate matter measurement system. The evaluation was conducted during simulated work activities.

"Projecting a green image", reduced Hand and Arm Vibration, reduced noise levels and reduced air pollutants emissions played a substantial part in the decision making process.

Methods

A new decision making model was developed to evaluate a new product intended for export. This research identified potential areas of SH&E professional involvement in the decision making process. The authors developed a new PtD model that incorporates risk assessment, hierarchy of controls, and future state risk reduction. The model follows Define, Measure, Analyze, Improve, and Control (DMAIC) logic. Separate tools were developed for each phase. For instance, brainstorming and Preliminary Hazard Analysis were used in the "Define" phase. A modified Bow Tie diagram, Risk Assessment matrix, and Failure Mode Effect Analysis (FMEA) were used in the "Measure" phase.

Applicability of FMEA tools to prioritize the hazards and modify the procedures was utilized to demonstrate and quantify the risk reduction after the proposed SH&E improvements. Hand and Arm Vibration, noise levels and air pollutants emissions were evaluated.

To demonstrate the applicability of the PtD model integration into ISO 31000 risk management process, the authors evaluated two different products as discussed in the following case study.

Results

Utilization of ISO 31000/ ANSI/ASSE Z690.2-2011, PtD, FMEA and Risk Assessment methodologies and a new model are estimated to significantly reduce the ergonomics injuries, noise levels and air pollutants of the product evaluated in this case study. Similar benefits are possible with products made in the US but intended for the European Union market. Possible SH&E practitioners' involvement in the process was evaluated.

<u>Hand and Arm Vibration Evaluation:</u>

Three industrial cleaner vacuum units were evaluated utilizing VibTrack / HAVSense system. HAVSense is an autonomous vibration dosimeter that records the operator's exposure to hand and arm vibration. HAVSense provides monitoring that satisfies the requirements of the European directive 2002/44/EC. (European Agency for Health and Safety at Work, 2002) The directive was issued in June 2002 and defines the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibration) and forms the sixteenth individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC. European directive 2002/44/EC lays down minimum requirements, in particular the fixing of lower values for the daily exposure limit value for vibrations. The European Directive acknowledges the possible damaging consequences of vibration for human health and lays down maximum levels of vibration exposure.

The HAVSense sits between the second and third fingers of either hand. The topside rests over the fingers. The underside rests under the fingers and is pressed by the fingers against the operating surface. The HAVSense was placed comfortably inside a protective glove for the data collection (see Figure 2).

Figure 2. HAVSense sensor inside operator's glove

Exposure data was downloaded directly to a computer via the docking station. To calculate the exposure, the team used the British Health and Safety Executive (HSE) Hand-arm vibration exposure calculator. The assessment of the vibration exposure is calculated in relation to a standardized 8 hr daily exposure value A(8). After establishing the A(8) value, this should be compared with the exposure action- and limit-values. Different units could be compared based on the daily Exposure Action Value (EAV) and the daily Exposure Limit Value (ELV).

Exposure Action Value (EAV)
Whenever an operator is subjected to vibration exposure A(8) exceeding the EAV at 2.5 m/s^2, the employer must carry out a risk assessment of the operation and introduce control measures. For more details, see Directive 2002/44/EC and Member State legislation.

Exposure Limit Value (ELV)
In any event, workers shall not be exposed above the ELV (5.0 m/s^2).

Results revealed that the right hand of the operator is exposed slightly more than the left hand.

British Health and Safety Executive (HSE) Hand-arm vibration exposure calculations made by the survey team for left hand exposure are shown in table 1. (Health and Safety Executive A, nd; Health and Safety Executive B, nd).

HAND-ARM VIBRATION EXPOSURE CALCULATOR Version 3 June 2005

HSE Health & Safety Executive

	Vibration magnitude m/s^2 r.m.s.	Exposure points per hour	Time to reach EAV 2.5 m/s^2 *A*(8)		Time to reach ELV 5 m/s^2 *A*(8)		Exposure duration		Partial exposure m/s^2 *A*(8)	Partial exposure points
			hours	minutes	hours	minutes	hours	minutes		
Tool or process 1	5.3659	58	1	44	6	57	3	24	3.5	196
Tool or process 2	0						0			
Tool or process 3										
Tool or process 4										
Tool or process 5										
Tool or process 6										

Instructions for use:

Enter vibration magnitudes and exposure durations in the white areas.
To calculate, press the Enter key, or move the cursor to a different cell.
The results are displayed in the yelllow areas.
To clear all cells, click on the 'Reset' button.
For more information, click the HELP tab below.

Daily exposure m/s^2 *A*(8)	Total exposure points
3.5	196

Table 1. Hand-Arm vibration sampling data – left hand.

HSE Hand-arm vibration exposure calculations for right hand exposure made by the survey team are shown in table 2.

HAND-ARM VIBRATION EXPOSURE CALCULATOR Version 3 June 2005

HSE Health & Safety Executive

	Vibration magnitude m/s^2 r.m.s.	Exposure points per hour	Time to reach EAV 2.5 m/s^2 *A*(8)		Time to reach ELV 5 m/s^2 *A*(8)		Exposure duration		Partial exposure m/s^2 *A*(8)	Partial exposure points
			hours	minutes	hours	minutes	hours	minutes		
Tool or process 1	7.9648	127	0	47	3	9	3	24	5.2	432
Tool or process 2	0						0			
Tool or process 3										
Tool or process 4										
Tool or process 5										
Tool or process 6										

Instructions for use:

Enter vibration magnitudes and exposure durations in the white areas.
To calculate, press the Enter key, or move the cursor to a different cell.
The results are displayed in the yelllow areas.
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For more information, click the HELP tab below.

Daily exposure m/s^2 *A*(8)	Total exposure points
5.2	432

Table 2. Hand-arm vibration sampling data – right hand.

As the reader has noticed there was a difference in the vibration measurements for the right and left hands. The difference could be explained with the fact that the operator is right handed. In addition, the design of the units could be another contributing factor.

The operator should not operate/run industrial vacuum cleaner more than 3.1 hours based on right hand exposure alone. Right hand exposure is considered a worst-case scenario.

Noise measurements:

The same units were evaluated for nose exposure. The sampling was conducted based on 2000/14/EC requirements.

OSHA sets legal limits on noise exposure in the workplace in the US. These limits are based on a worker's time weighted average over an 8 hour day. With noise, OSHA's permissible exposure limit (PEL) is 90 dBA for all workers for an 8 hour day. (Occupational Safety and Health Administration, nd).

The OSHA standard uses a 5 dBA exchange rate. This means that when the noise level is increased by 5 dBA, the amount of time a person can be exposed to the new noise level (now 95 dBA) to receive the same dose is cut in half (or 4 hours).

The National Institute for Occupational Safety and Health (NIOSH) has recommended that all worker exposures to noise should be controlled below a level equivalent to 85 dBA for eight hours to minimize occupational noise induced hearing loss. (National Institute for Occupational Safety and Health, nd). NIOSH also recommends that the exchange rate be 3 dBA.

The British HSE Noise Regulations also require specific action at certain action values. Health and Safety Executive (2005). These relate to:

Lower exposure action values:

- daily or weekly exposure of 80 dB;
- peak sound pressure of 135 dB;

Upper exposure action values:

- daily or weekly exposure of 85 dB;
- peak sound pressure of 137 dB.

There are also levels of noise exposure that must not be exceeded. These are called exposure limit values:

- daily or weekly exposure of 87 dB;
- peak sound pressure of 140 dB.

None of the tested units exceeded 85 the dBA noise level.

PM exposure measurements:

Two units were tested for particulate matter (PM) emissions using a DustTrak DRX PM Measurement system. The purpose of the test was to evaluate the PM levels approximately one (1) meter from the dust collection system.

Occupational Size-selective Criteria and Particles Size Sampling

Occupational health and safety professionals have traditionally sampled for two particulate size fractions: total or respirable. (Occupational Safety and Health Administration, nd).

Total particulate includes both respirable and non-respirable particles, a.k.a Particulates not otherwise regulated (PNOR). OSHA Permissible Exposure Limit (PEL) **- 15 mg/m^3 (15000 $\mu g/m^3$) TWA**

Respirable particulate includes only the smaller particles than can penetrate to the alveolar or gas-exchange region of the lung. PNOR *Respirable Fraction* - OSHA PEL **- 5 mg/m³ (5000 µg/m³) TWA**

At this time, U.S. OSHA and MSHA still use total and respirable particulate size fractions for regulatory standards and compliance monitoring.

The company's engineering unit designed a special filtering dust containment system to reduce the PM pollution and operators' exposure. The results are presented in the table and the chart below.

	Respirable particles 4 µg/m³	Total PNOR µg/m³
Used Dust Containment System	72.45	81.53
New Dust Containment System	91.8	107.12
No Dust Containment System	118.275	161.7
No Bag	296.95	367.63

Table 3. PM exposure measurements

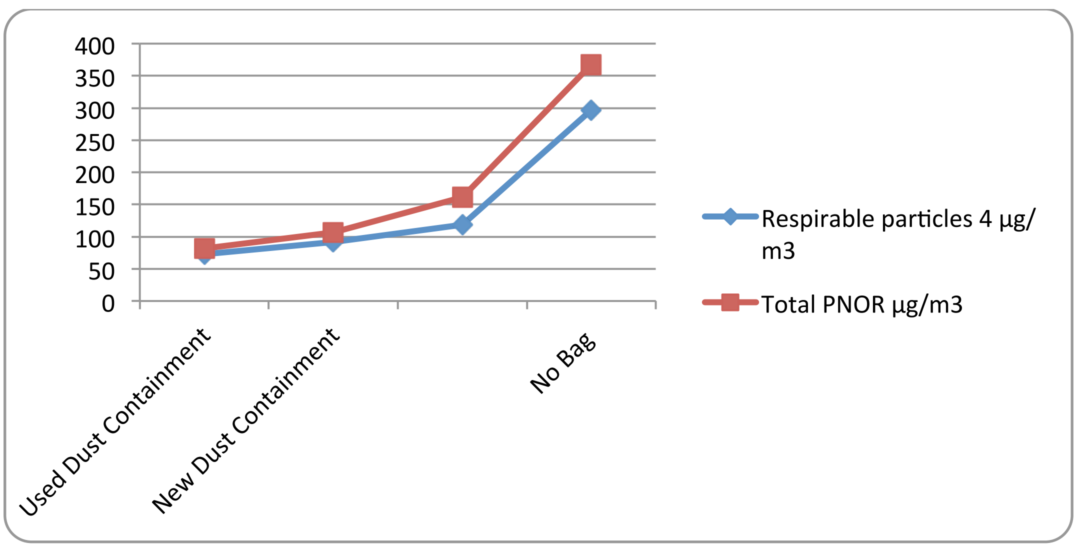


Figure 3. Dust exposure measurements in µg/m³

Figure 3 visualizes the results. The used dust containment system is the most efficient. It provides reduced operator exposure and it is more protective of the environment. The new unused dust containment system is also effective. However, it might be concluded that the collection efficiency increases with accumulation of the particles on the inner surfaces of the filtering bag.

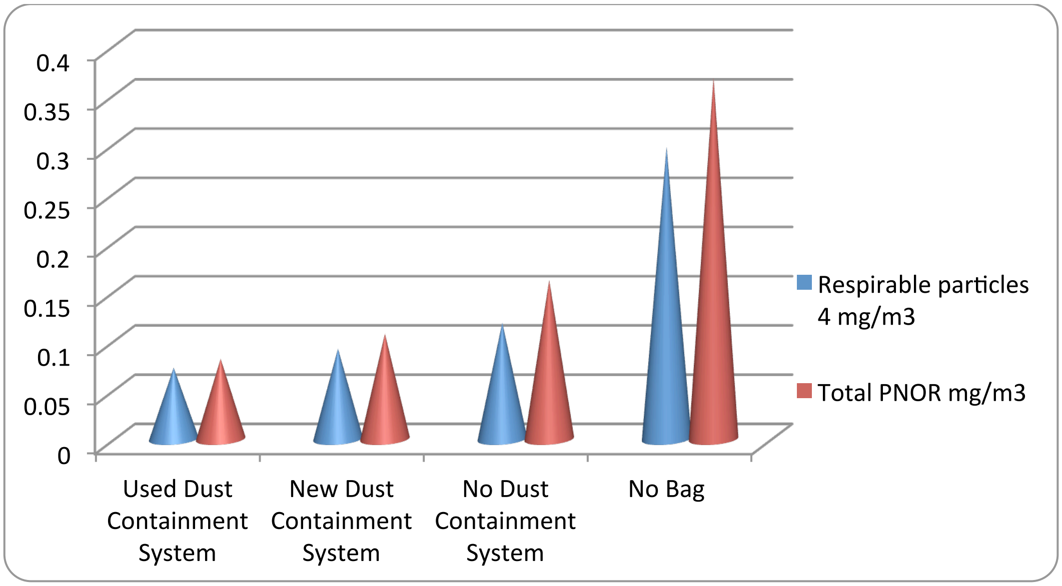


Figure 4. Dust exposure measurements in mg/m^3

The sampling results indicate potential operator exposure is well below occupational exposure limits.

After a careful evaluation of the results, the team developed a new PtD model. The model follows Define, Measure, Analyze, Improve, and Control (DMAIC) logic. (Popov G, Zey JN, 2012). Please see the PtD model below.

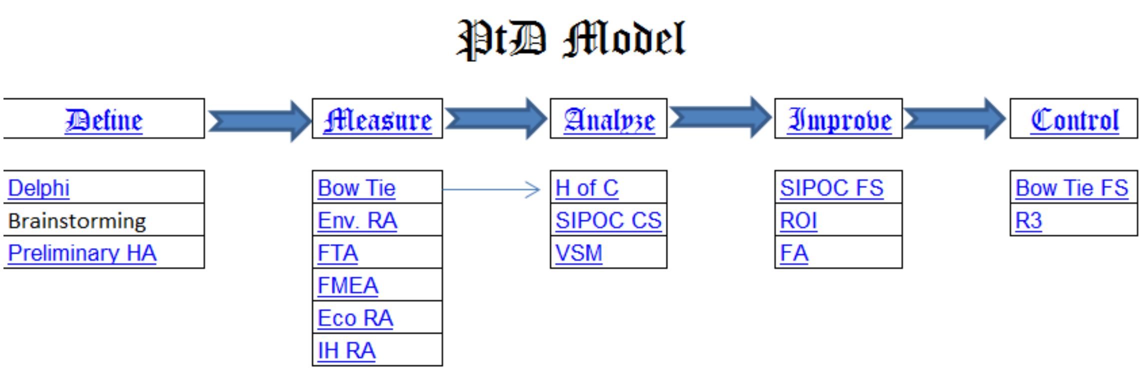


Figure 5. The PtD Model

During the Define phase, Preliminary Hazard Analysis (PHA) was performed for Hand-arm vibration, Noise and PM exposures. The current state PHA example is presented in Figure 6.

Project/Process	
Prepared by:	Dr. G. Popov

Methods Used			
Hazardous Event	System Effects	RF or RPN	Comments
Wrist injury	Operator affected	27	
HAVS	Operator affected	24	
Noise	Operator and Community affected	9	

Figure 6. Current state PHA

Risk Priority Number (RPN) can be calculated using standard FMEA and RPN worksheet.

FMEA & RPN Worksheet

Part or Process Name	Trash Pick	Suppliers &				Prepared By			
Design/ Mfg Responsibility		Model Date				FMEA Date			
Other Areas Involved		Engineering Chang							
Process Operation, Function or Purpose	Potential Failure Mode	Potential Effect(s) of Failure	SEV	Potential Cause(s) of Failure	OCC	Current Controls Evaluation Method	PE	S x O	RPN
Trash/ leaves collection	Ergo injury	Wrist injury	3	Design	3	Admin	3	9	27
									
Trash/ leaves collection	Hands and Arms	HAVS	4	Vibration	2	Admin	3	8	24
									
Trash/ leaves collection	Noise	Hearing loss	3	Improper Exhaust Design	1	None	3	3	9
									

Figure 7. FMEA & RPN Worksheet

Where:

SEV – Severity; OCC – Occurrence/Probability; PE- Prevention Effectiveness.

Based on the initial limited hazard analysis, a bow-tie risk assessment diagram was prepared. Figure 8 presents the current state risk assessment.

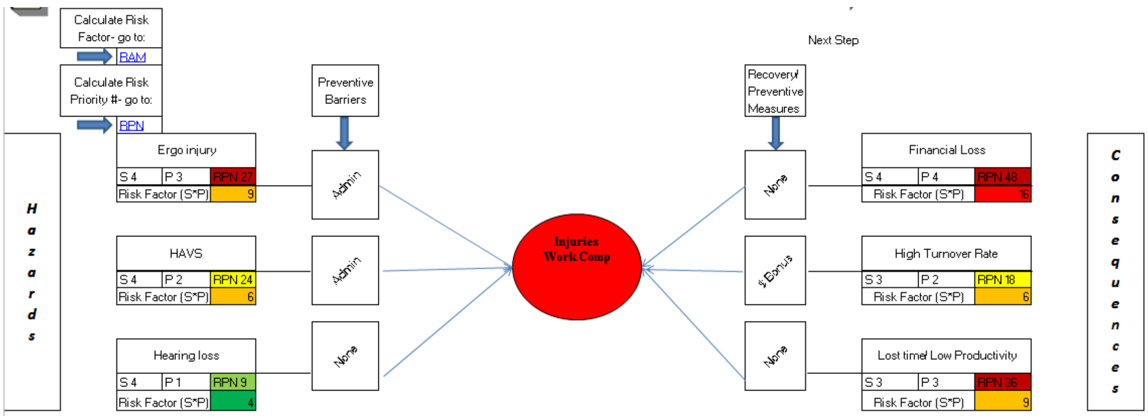


Figure 8. Current state risk assessment

The PtD Hierarchy of Controls (see Figure 9) was utilized to develop suggestions for engineering controls. A better handle design was suggested. Polyurethane dampers could reduce vibrations and a new muffler and lower RPMs could further reduce noise.

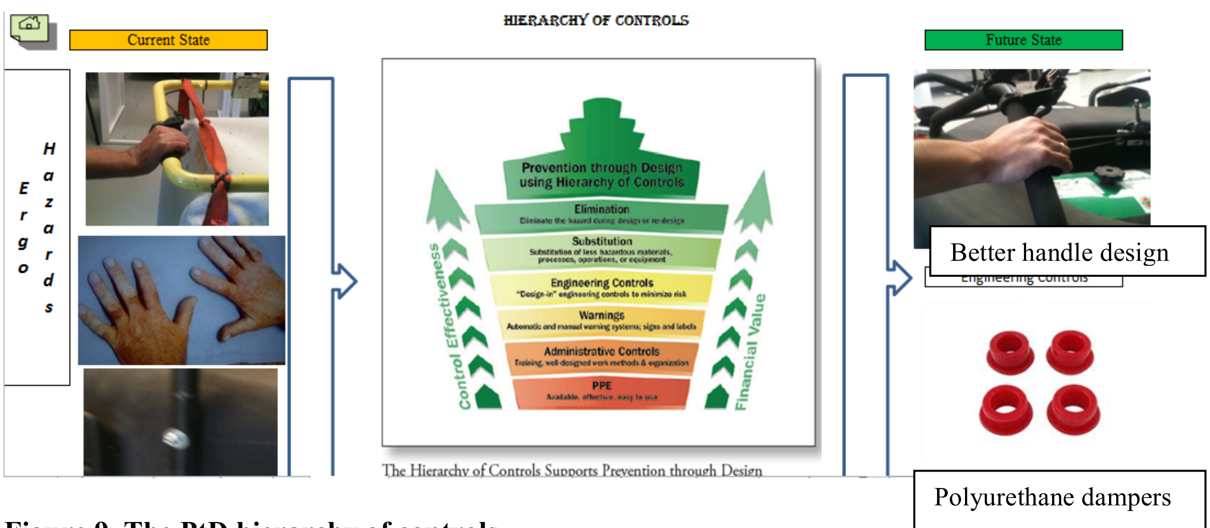
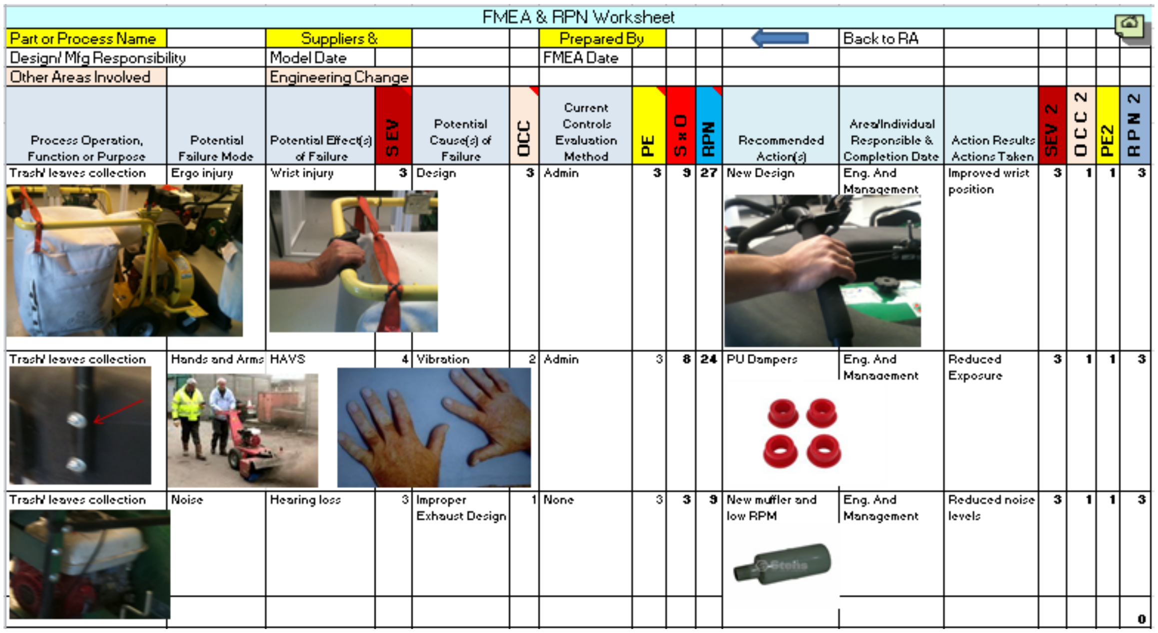


Figure 9. The PtD hierarchy of controls

Based on PtD improvements, future state FMEA RPN were calculated (see Figure 10).



FMEA & RPN Worksheet

Part or Process Name		Suppliers &				Prepared By					Back to RA					
Design/ Mfg Responsibility		Model Date				FMEA Date										
Other Areas Involved		Engineering Change														
Process Operation, Function or Purpose	Potential Failure Mode	Potential Effect(s) of Failure	SEV	Potential Cause(s) of Failure	OCC	Current Controls Evaluation Method	PE	S x O	RPN	Recommended Action(s)	Area/Individual Responsible & Completion Date	Action Results Actions Taken	SEV 2	OCC 2	PE2	RPN 2
Trash/ leaves collection	Ergo injury	Wrist injury	3	Design	3	Admin	3	9	27	New Design	Eng. And Management	Improved wrist position	3	1	1	3
Trash/ leaves collection	Hands and Arms	HAVS	4	Vibration	2	Admin	3	8	24	PU Dampers	Eng. And Management	Reduced Exposure	3	1	1	3
Trash/ leaves collection	Noise	Hearing loss	3	Improper Exhaust Design	1	None	3	3	9	New muffler and low RPM	Eng. And Management	Reduced noise levels	3	1	1	3
																0

Figure 10. Future state FMEA

Future state bow-tie risk analysis was prepared based on the future state RPNs (see Figure 11.)

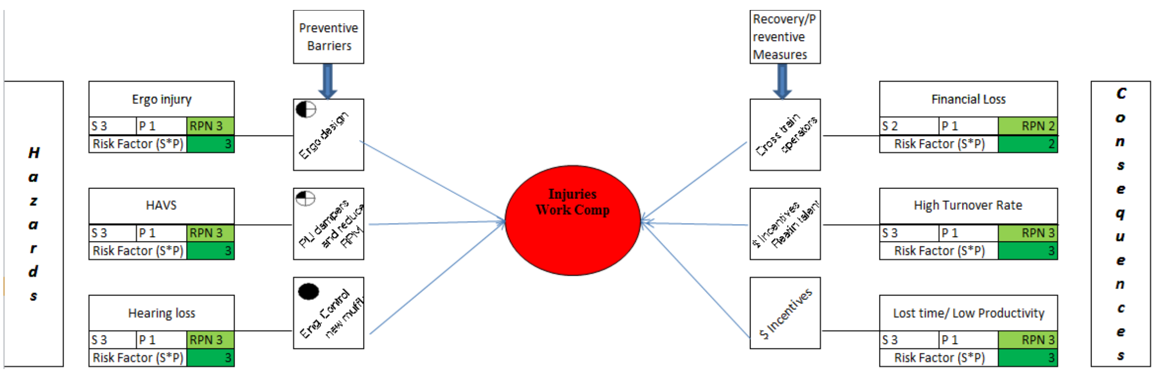


Figure 11. Future state bow-tie analysis

Additionally, Residual Risk Reduction (R3) was calculated. SH&E improvements resulted in a 52.6% (SxP) and 85% (RPN) risk reduction (see figure 12).

Residual Risk Reduction (R3)						
	Hazards	Risk Factor CS	Risk Factor FS	RPN CS	RPN FS
	Ergo Injury	9	3	27	3
	HAVS	6	3	24	3
	Hearing Loss	4	3	9	3
	Total	19	9	60	9
R3=(RF CS-RF FS)/RF CS*100 %		52.63158	52.63 %	85	85.00 %

Figure 12: Residual Risk Reduction

Where:

Risk factor is Severity times Probability, and

RPN is Severity times Probability and Prevention Effectiveness.

The authors have used Residual Risk Reduction (R3) methodology and Liberty Mutual's formula to calculate percent reduction. (Liberty Mutual, 2010). It should be noted that the R3 Rating Scale provides for numerical ratings that may be assigned to three key characteristics–frequencies (F), likelihood (L), and severity (S)–when a particular area of risk is evaluated (Liberty Mutual, 2010). However, the authors feel confident that the same formula can be used to compare risk reduction for three or more hazards.

Conclusion

SH&E professionals can play a significant role in new products development. PtD can be successfully integrated into the ANSI/ASSE Z690.2-2011 (ISO 31000) Risk management process. The project described in this paper led to a decision by management to approve the new product design, which will result in reduced ergonomics injuries, reduced emissions and improved operator productivity. These changes should also enhance the company's abilities to sell their products in Europe.

It was concluded that PtD tools could be successfully incorporated in the Risk Management process. Such process could be used effectively to develop and present a business cases for Environmental, Health, and Safety interventions.

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