

Integrating Predictive Risk Analysis and Dynamic Risk Assessment into traditional safety and health risk assessment

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Abstract

A 'risk' means the likelihood that a hazard will cause a specific harm or injury to persons or damage to property. The formal definition of Risk (adopted by ISO 31000) accepts that risk is the effect of uncertainty on objectives. Predictive Risk Analysis assist in predicting a failure or risk that can occur especially for rotating and non-rotating equipment such as machinery, valves, and tanks. is a real-time, continuous process of identifying and mitigating hazards while a task is being performed It is used in situations with unpredictable or changing conditions and allows workers to make quick, informed decisions on the spot by continuously observing, analysing, and acting on new risks as they arise. Traditional Risk Assessment considers an activity, breaks down the activity into sub-activity considers hazards in each sub activity, then considers severity and likelihood and subsequently the risk based on severity and likelihood. Traditional Risk Assessment are done for routine and non-routine activities. As and when required dynamic risk assessments are done. Predictive Risk Analysis is done at the beginning of installation of tanks, pumps etc. Thus there is a greater advantage on integrating the three risk assessments into one for a comprehensive, realistic risk assessment and controls.

Key words: Predictive Analysis, Dynamic Risk Assessment, Severity, Likelihood.

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I. Introduction

Risk management is the process of identifying, evaluating and controlling risks at the workplace. Every workplace must conduct regular risk assessments, The Workplace Safety and Health (Risk Management) Regulations state that employers, self-employed persons and principals (including contractors and sub-contractors) are responsible for identifying safety and health hazards at workplaces and taking measures to eliminate or reduce the risks. Fig -1 shows the difference between Subjective and Objective Risk Assessments.



In recent years, the landscape of Environmental, Health, and Safety (EHS) risk management has been dramatically transformed by advancements in Artificial Intelligence (AI) and Data Analytics (DA). Predictive analytics (PA), in particular, has emerged as a powerful tool that empowers organizations to anticipate, identify, and mitigate potential risks before they escalate into significant issues.

1. A dynamic risk assessment (DRA)*³

DRA is a real-time, continuous process of identifying and mitigating hazards while a task is being performed. It is used in situations with unpredictable or changing conditions and allows workers to make quick, informed decisions on the spot by continuously observing, analysing, and acting on new risks as they arise. A DRA supplements, but does not replace, a formal risk assessment. DRA identifies and responds to hazards as they change in a real-time environment, is conducted continuously, often "on the spot" or throughout an entire operation. DRA adapts to new information and changing circumstances by continuously monitoring and re-evaluating risks using live data, such as real-time sensor data or weather forecasts and the method is ideal for unpredictable or high-risk situations, such as a construction worker reassessing the risks on a daily or even hourly basis as conditions change. A dynamic risk assessment is a process of quickly identifying risks and hazards in a workplace where the situation is dynamic and risks can change due to rapidly changing conditions. Other terms used interchangeably with Dynamic Risk Assessment include Real-time Risk Assessment, Continuous Risk Assessment, Ongoing Risk Assessment, Active Risk Assessment, Rolling Risk Assessment, and Last-Minute Risk Assessment. The term 'Dynamic Risk Assessment' is commonly used to describe a process of risk assessment being carried out in a changing environment, where what is being assessed is developing as the process itself is being undertaken.

DRA is a continuous assessment of risk in a rapidly changing environment, to implement the control measures necessary to ensure an acceptable level of safety and risk. A dynamic risk assessment is a process of quickly identifying risks and hazards in a workplace where the situation is dynamic and risks can change due to rapidly changing conditions. It is conducted by competent persons in charge to implement control measures and mitigate dynamic risks. A **Dynamic Risk Assessment (DRA)** is a continuous process of identifying hazards, assessing risks, and taking action to eliminate or reduce them in rapidly changing, unpredictable environments. Unlike static risk assessments, which are completed ahead of time on paper, a DRA is a mental process performed on-the-spot by individuals facing real-time hazards.

While a DRA is mostly qualitative in everyday practice (e.g., used by first responders or frontline workers), the broader field of **dynamic risk analysis** can incorporate **quantitative** elements when dealing with complex, automated industrial or engineering systems. It can become quantitative when it relies on hard data and mathematical modelling. It calculates specific probabilities (percentages) and potential impacts using statistical models, sensor data, and historical records.

Imagine a construction site where workers are excavating a trench for laying pipelines. As the work progresses, a heavy rainstorm suddenly hits the area, leading to several changes in the work environment and increasing the risk of accidents or hazards. Workers and supervisors assess the increased risks posed by the rainstorm, considering factors such as the likelihood of slips and falls, the stability of the trench walls, and the impact on equipment operation. Continuous monitoring of weather conditions and site conditions is essential to track changes and anticipate potential risks. Supervisors and safety personnel remain vigilant to identify any emerging hazards. Based on the assessment of risks, supervisors may decide to temporarily halt excavation work until the rain subsides to ensure worker safety. They may also implement additional safety measures such as providing non-slip footwear, installing barricades around the trench, or reinforcing trench supports.

2. How Predictive Risk Analysis work in Workplace Safety and Health

Analyses historical data: By studying past accidents, predictive models can identify patterns related to specific times, machines, or conditions, helping to focus prevention efforts. Predictive models can reveal high-risk zones in the oil & gas sector which can be identified as "red zones" with specific safety compliance requirements.

Uses real-time sensor data: Sensors in machinery can detect anomalies like unusual vibrations or temperature spikes, which can be analysed to predict mechanical failure before it happens. Sensors on equipment, like those used in the oil and gas industry, monitor factors like vibration, temperature, and pressure in real-time. These sensors can forecast which equipment is at high risk of failure or breakdown before it happens, allowing maintenance to be scheduled in advance. This prevents dangerous situations like blowouts or equipment malfunctions that could injure workers. For instance, predictive analytics can detect when machinery such as a conveyor belt in a manufacturing unit might fail, warn when certain areas near a tower crane operation in a construction site suddenly get overcrowded, and even alert EHS managers if a work seems to display unusual behaviour such as signs of stress or fatigue.

Monitors human behaviour: In some environments, wearables or other tracking systems can analyse worker behaviour to flag unsafe practices, such as not wearing protective gear. By analysing a wide range of data, such as historical incident reports, safety inspection results, and near-misses, predictive analytics can identify correlations and patterns. These wearables, can pinpoint specific areas within a facility that have a higher probability of future incidents or identify certain behaviours that correlate with risk. This allows safety managers to implement targeted training programs, allocate resources more effectively to those areas, and proactively address potential hazards before they lead to accidents. **Identifies high-risk scenarios:** Models can combine various data points, including environmental conditions and equipment performance, to predict high-risk scenarios. These models can pinpoint specific areas within a facility that have a higher probability of future incidents or identify certain behaviours that correlate with risk. This allows safety managers to implement targeted training programs, allocate resources more effectively to those areas, and proactively address potential hazards before they lead to accidents.

Enables early intervention: The core benefit is enabling proactive intervention. By identifying potential failures or unsafe conditions early, companies can take action to prevent an accident from occurring

When to use predictive risk analysis.

- Before starting new processes: Conduct an assessment before a new activity or process is introduced to the workplace.
- Before implementing changes: Perform an analysis before making changes to existing processes, such as updating equipment or machinery.
- As a continuous process: Use predictive analytics to constantly monitor for potential hazards by analysing real-time and historical data.
- When new information arises: Perform an assessment when new information becomes available concerning a potential harm or risk.
- Enhancing compliance and regulatory reporting by enabling organizations to proactively manage their adherence to various laws, standards, and regulations.

Here are some of the top predictive analytics*⁶ models that have health and safety applications.

- The forecast model - This model of predictive analytics focuses on specific metric value prediction with the model learning from historical data and generating new forecast data. Any safety situation in which historical data can be processed can make use of this predictive analytics model. For example, a safety assessor or professional could predict the amount of missed or faulted risk assessments that may occur within a specific period.
- The classification model - This is one of the most widely used and simplest forms of predictive analytics. The fundamental principle behind it is that it classifies the data that you generate from the input into your model. From a safety and health risk assessment point of view, for example, the likelihood that a specific piece of equipment may be faulty in a certain timeframe.
- The outlier's model - The outlier's model is particularly useful in health and safety as it identifies anomalous data within a series. Not only can it categories information, but if the input data is correct, it can identify anomalies which may indicate a specific area where a safety concern needs to be addressed. Example of its use include an anomaly in real-time sensor data (like a sudden temperature spike) could flag a potential gas leak or equipment malfunction. A series of factories or plants in which incidents are recorded over time, if a spike is recorded during a certain period, an outlier's model could identify the data in addition to potential anomalies in parameters (like air quality) which may be present in different factories.
- The Regression models - estimates a continuous outcome based on historical data. (which predict specific outcomes like the number of incidents). Example include Predicting the exact number of missed or faulty risk assessments that might occur over a specific period.

3. Conventional/Traditional l Safety and Health Risk Assessments (TRA):

TRA are often planned ahead of time and occur at frequent intervals (for example, yearly) to monitor and manage risk levels. Among the many models adopted for Safety and Health Risk Assessment is the activities-based Risk Assessment (TRA). TRA is widely used for activities, where hazards are identified and their potential impact or severity. Based on the likelihood of the occurrence, risk levels are identified as the multiplication of likelihood and severity.

Difference between Traditional Risk Assessment (TRA), Dynamic Risk Assessment (DRA) and Predictive Risk Analysis (PRA) is shown in the below Table -1

Measure	TRA	DRA	PRA
When to use	Activity based before the commencement of the activity	to being carried out in ad hoc situations.	Typically, when new or existing plant, equipment, process is introduced
Type	Qualitative or subjective assessment of likelihood and severity.	Semi Qualitative or Quantitative it is a real-time process of evaluating and managing hazards in rapidly changing situations,	Semi Qualitative or Quantitative Data-driven and objective prediction based on historical data and algorithms.
Risk Scoring	Risk = Likelihood x Severity	it relies on the assessor's on-the-spot judgment, intuition, and experience to categorize risks (e.g., high, medium, or low)	Risk score = Predictive likelihood x Quantified impact
Example on a scale of 5	Risk = 3 x 4 = 12	Directly eliminated	Risk = 3 (likely) x 4 (severity based on impact) = 12
Scoring	Often uses descriptive scales (e.g., "high," "medium," "low") or simple numerical scales.	Generally used to reduce the risk directly	Generates a precise numerical risk score through statistical analysis.
Risk Evaluation	Based on current or historical knowledge, which can be prone to bias	Risk evaluation is based	Forecasts future risks and potential outcomes, providing a forward-looking view.
Resource allocation	Risks are prioritized based on subjective evaluation, which can lead to misallocation of resources.	On the job assessment, may require technological tools like smart helmets, smart clothing.	Risks are prioritized based on their data-driven score, ensuring resources are focused on the highest-priority threats.

4. How to integrate PRA and DRA into TRA

The correct order is predictive analysis, then risk assessment, and finally dynamic risk assessment, as predictive analysis provides the data to inform a general risk assessment, which is then refined in real-time by a dynamic risk assessment. Fig -2 shows the schematic of holistic safety and health risk assessment.

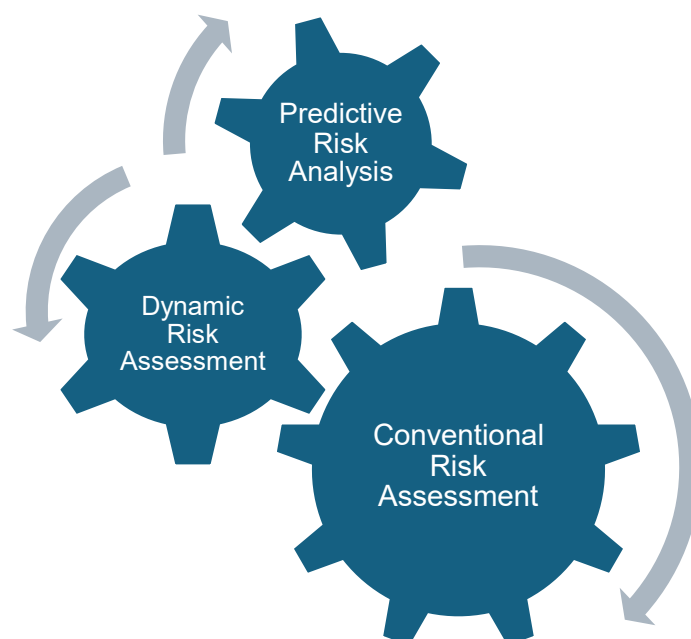


Fig 2– schematic of holistic safety and health risk assessment.

Step 1 - Predictive analysis

- This is the first step, involving the use of historical and current data to forecast future outcomes and identify potential risks.

- It uses data analysis and modelling to identify potential risks before they happen, setting the stage for the next phase.

Step 2 - Risk assessment

- This is the process of evaluating the risks identified in the previous step.
- It involves identifying hazards, determining who might be harmed, and evaluating the risk to decide on precautions.
- This is a more formal, often static process compared to dynamic risk assessment.

Step 3 - Dynamic risk assessment

- This is a real-time, ongoing process that refines the initial risk assessment as a situation evolves.
- It is applied in environments where risks can change rapidly and requires constant reassessment and adjustment of control measures.

Example of an Integrated Risk Assessment using 5x5 matrix.

Modes	Hazard	Likelihood	Severity	Risk Level	Risk Profile	Method
Work in tank 6 m above ground constructed 15 years ago	Fall from heights	3	5	15	High	TRA
	Tank rupture	1	10	10	Medium	PRA
	Extreme weather conditions leading to fatigue	4	2	8	Medium	DRA

Integrated Risk Assessment Analysis

For the same activity of process, PRA, DRA and TRA gives a different risk profile. Thus, the highest risk profiles should be considered for organisation. Based on the risk levels from each of the three methods, highest risk rating are considered and control measures are accordingly determined. It should also be noted that controls to DRA risk are usually decided on the spot.

II. Conclusion

Predictive analytics^{*2}, in particular, has emerged as a powerful tool that empowers organizations to anticipate, identify, and mitigate potential risks before they escalate into significant issues. The integration of predictive risk analytics and Dynamic Risk Assessment into EHS risk management not only enhances operational efficiency but also fosters a proactive safety culture within organizations. By moving from a reactive approach to a predictive mindset, EHS managers can engage employees in risk management efforts, empowering them with the knowledge and tools to identify potential hazards and contribute to a safer workplace.

Assessments you could not predict when completing your standard risk assessment. Organization should carry out a dynamic risk assessment before entering any new situation and continue to assess the risks and hazards. The integration of Dynamic Risk Assessment and Predictive risk analytics into traditional EHS risk management not only enhances operational efficiency but also fosters a proactive safety culture within organizations. By moving from a reactive approach to a predictive mindset, EHS managers can engage employees in risk management efforts, empowering them with the knowledge and tools to identify potential hazards and contribute to a safer workplace.

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