Building Risk Intelligence

Thábata Maciel, Cynthia Spitzenberger, Brian Bain
DNV GL

DATA TO INTELLIGENCE HIERARCHY

Data is only of value to a business if it can be used to inform a decision. To achieve this the data must be presented in a way in which enables the creation of intelligence within the individual or organisation making that decision. The path from data to intelligence is known as the "Data-Information-Knowledge-Intelligence" hierarchy, and was first proposed as a structured model by Russel Ackoff, in 1989 [1]. A key stage in this process is how the data is presented in a structured way, i.e. as information. This is true for many technical and commercial activities including safety risk management. This paper demonstrates how risk data can be presented in ways which builds risk intelligence more effectively than can be achieved by using a traditional reporting format.

The word "intelligence" comes from the latin "*intelligere*", and was formed by the combination of the words "*inta*" and "*legere*". The former is a readily recognizable prefix in many modern languages, and means "between". The latter, however, is not so straightforward, as it can translate to "read" or to "choose", but was also commonly used in ancient Greek to refer to the wooden sticks used to align writings in stones. From the combination of these two words, it can be seen that "intelligence" infers the ability to read between the lines.

Reading what is not written, or understanding the meaning behind information, is a core human trait. As we develop as a species, its importance becomes more and more prominent, to the point of becoming a globally acknowledged asset in today's businesses. The volume of data is increasing exponentially, but real value can only be found in the ability to refine it into intelligence.

According to Ackoff's model, data, in its natural form, is of no use, since it is merely the product of observations, such as numbers, signals, etc. Information, on the other hand, is recognizing the data as a measure of something. A number can be the representation of a date, age, or even a binary code, and putting it into context promotes it to the level of Information. The third level is Knowledge, the collection and interpretation of information.

Collation of information allows interpretation of how different parts relate to each other, and to draw conclusions for "how"-type questions. Recognizing that the planet is getting warmer, for instance, requires the combination of multiple pieces of information from different parts of the globe, and over a period of time, in order to acquire sufficient experience and correctly interpret it; the definition of knowledge. Finally, intelligence is the final layer of the hierarchy and requires the highest level of cognitive skills. It represents the extrapolative process of applying knowledge to solve current and future problems. By means of adaptations and analogies, intelligence builds on knowledge to allow better decision making.

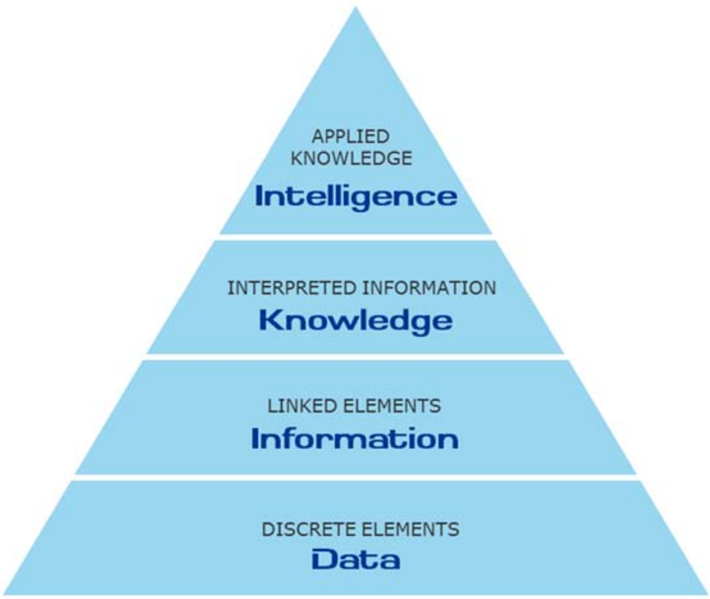

Figure 1 – Pyramid of the Data-Information-Knowledge-Intelligence hierarchy

From "Data" (discrete elements), "Information" (linked elements), "Knowledge" (interpreted information), and "Intelligence", (the ability to apply knowledge), the hierarchy can be represented as a pyramid (Figure 1). Starting at the base, this format represents the abundancy of data we have access to, and how, as we refine it, it becomes more condensed. Information comes from a large amount of Data; similarly, Knowledge is distilled from the Information gathered, and Intelligence is based on a substantial amount of Knowledge. Within this structure, there is no point in hoarding data just for the sake of it; what matters is the refinement process to develop intelligence. Nevertheless, Data forms the foundation.

TRADITIONAL RISK REPORTING

The traditional approach to disseminate technical information has served the scientific and engineering communities well for centuries. It is the reason why humans have advanced so rapidly since the middle ages. Discoveries and technical advances were communicated to others working in the same field in other parts of the world so that each generation could stand on the shoulders of previous giants, see further, and take the next step forward. With each generation, the intelligence associated with a given scientific/technical area grew.

Nowadays, the approach for risk assessment of industrial facilities has evolved in such a way to produce very detailed results. These results form the input to the decision making process, and therefore, in this context, they can be viewed as Data. It has evolved into a complicated process that can take weeks or months to be concluded. Traditional reports for risk studies of large facilities can reach 500 pages or more, depending on the documentation requirements. Communication of risk results usually involves providing the reader with the most important conclusions of the analysis. A static report, however, cannot possibly provide the full set of data and information, as it would be far too large and difficult to digest.

Requirements to preserve detailed inputs, calculations and outputs from risk assessments are understandable, given that this data is meant to be retained for possible future reference. However, risk calculation techniques have evolved disproportionately compared to the way results are reported. Very robust risk models are being developed each day, and it has become impractical to document every intermediate calculation and end result in a traditional reporting format (Figure 2).

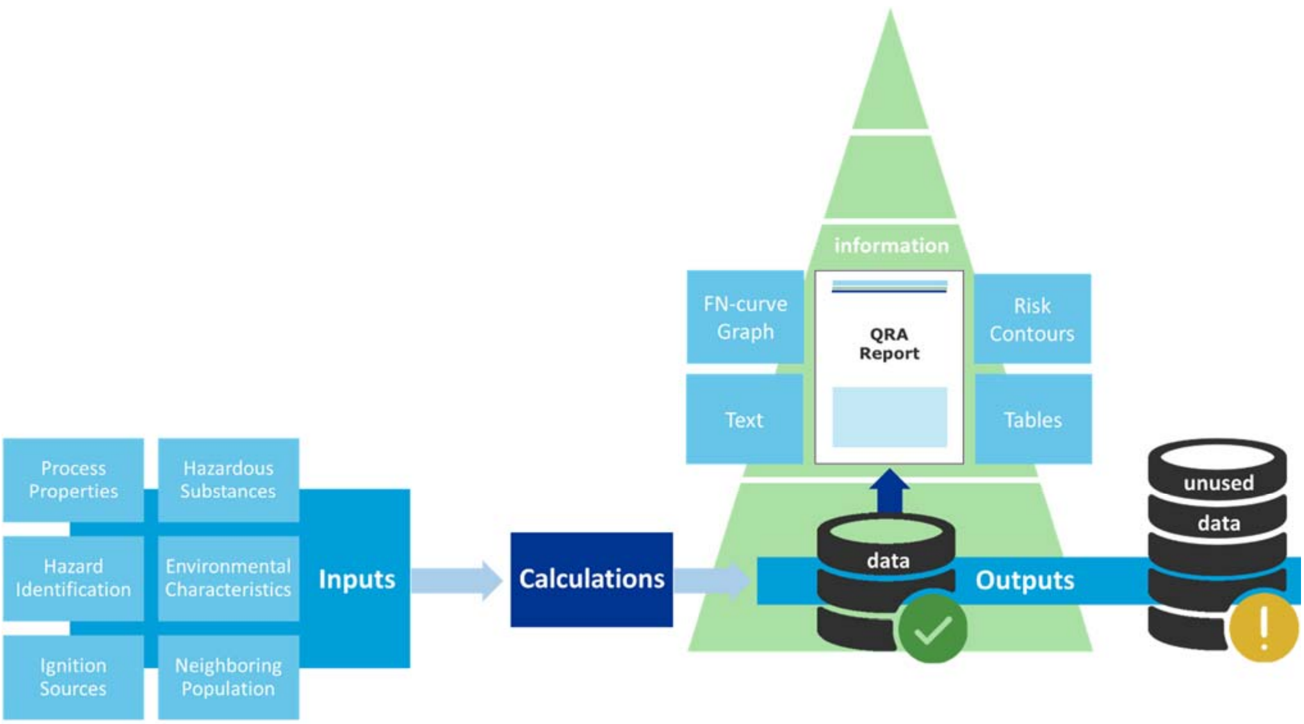

Figure 2 – Traditional Risk Reporting Process and Generation of Unexplored Outputs

The traditional approach has limitations. It takes time to write the report, technical paper or news item, and even more time to have it printed and distributed. Advances in communication and the ability to transmit data electronically sped up this process. The advent of the digital age and the ability to send data globally, to multiple destinations effectively and instantly, have increased the speed of development.

Consequently, the amount of data available is now increasing at an exponential rate. Each year the total amount of data on the planet grows by 40% [2]. It is created relentlessly by everyone who uses a computer or takes a digital photograph. But data on its own is of no value unless it can be put to use, i.e. unless it can generate intelligence that can be used in decision making.

With so much data available, it is difficult for an organisation to isolate and absorb what is relevant to their problems and transform it through the data-information-knowledge-intelligence path. A detailed risk assessment can aggregate thousands of simulations, producing several gigabytes of data for a single installation. Presenting these in a raw format would take a user too long to assimilate and extract intelligence. This is particularly the case if the people responsible for making the decision are not themselves risk analysis practitioners. The challenge is to transform the numbers into a more easily digestible form.

Risk analysts are tasked with understanding and interpreting this data, i.e. converting it into information. The conclusions drawn from analysing and comparing the results lead to the creation of knowledge within the author's mind which hopes to transfer to the reader by means of the report. However, even when the reader has acquired this knowledge, using it to inform decision making – mitigate the frequency and/or consequences of accidents – requires a further, and most critical step. It requires foresight, and the ability to solve future problems based on current knowledge; it requires building intelligence.

Additionally, risk results are not normally the only input necessary to making a decision. Other aspects need to be considered, and each of these require data to be converted to information to build a strand of knowledge. Multidisciplinary strands need to be combined to reach a balanced decision. In this context, the reader of a risk report must combine the knowledge they gain with other areas, such as financial implications and production targets to effectively manage industrial facilities (Figure 3).

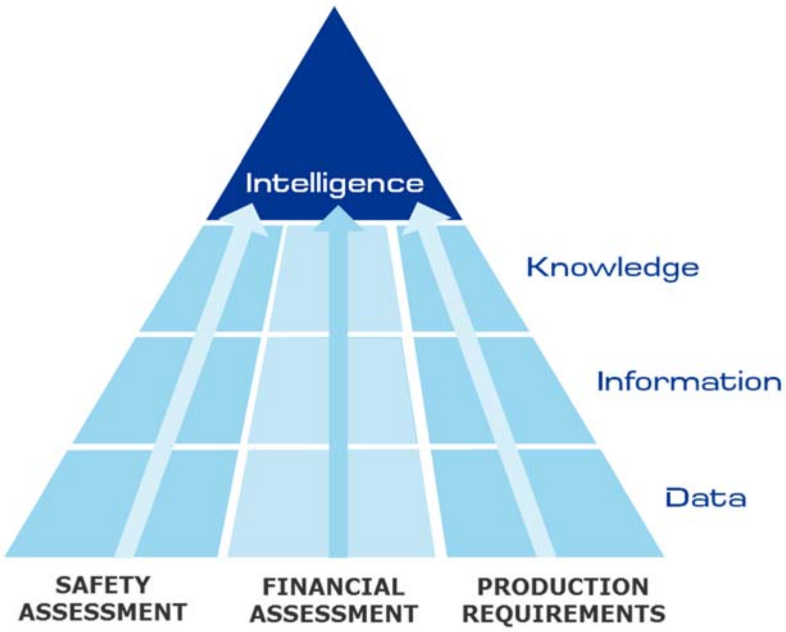

Figure 3 – Multidisciplinary Aspects Necessary to Build a Complete Data-to-Intelligence Hierarchy

CONVEYING DATA AS INFORMATION

Usually risk results are presented in a summary form – in tables, charts and graphs representing the magnitude of risk; information that might be very difficult for non-specialists to understand. Presenting results this way has clear limitations in communicating the risk picture to the various stakeholders. When a single static report is intended for both low and high-end consumption, it will either lack the detail technical specialists are looking for, or make it difficult to obtain an overview. There is a balance to be maintained: to provide detail for future questions and summarized findings to answer immediate issues.

Risk analysts need to provide a mechanism for this process and it may not be easy if one does not understand what intelligence decision makers are seeking: “Does the reader only want a high level summary or requires the underlying detail?” and “Which aspects of the report are most important?” are critical questions that analysts need to address. Decision makers may have only a limited amount of time to assess information and build intelligence, so it must be conveyed in a way for quick absorption. The solution to the dilemma lies not only in providing data, but also a mechanism for the user to isolate the information they are looking for and have it presented in a convenient form.

The traditional layout of a report has a lot of inertia, i.e. the scientific/engineering community has come to expect information to be communicated in this way. Even when the community no longer expects the report to be delivered as printed hard copies, it is still expected that the electronic version conforms to the traditional format. Reviewers like the familiarity of the data and commentary being presented in a series of pages that flow linearly. Hyperlinks that allow the reader to jump quickly between related sections is a step forward, but the tendency to present information in pages may be a self-imposed restriction that slows down the process of the reader transforming the data into intelligence.

Now that the constriction of producing the report in a set format has been removed, it opens up a range of possibilities to present data in a way which allows the recipient to develop intelligence faster and more effectively. For that purpose, some important traits should be aimed for, listed in Figure 4.

Complete	every item of data in the collection should be presented down to the smallest indivisible part
Searchable	the recipient must to be able to quickly find the piece of information needed
Structured	the data should be laid out in a logical manner
Aggregated	collections of related data should group together with sub-totals, averages, etc
Compact	the physical size should be manageable
Meaningful	the context should be clear and non ambiguous
Interesting	presented in a way that holds the recipients attention
Entertaining	information is easier to acquire if the experience is enjoyable

Figure 4 – Goals for Presenting Information

Some of these objectives are in apparent conflict with each other, such as Complete and Compact, Complete and Aggregated, Complete and Interesting. This is the dilemma: having a large amount of data available but presenting it in a summarised and interesting way. The solution is to lay-out the data in bulk and provide the recipient with a number of tools that allow them to interrogate and summarise it in a way which suits their needs. It is unlikely that most users will view the bulk data. This would be uninteresting and not provide them with information in a short timescale that can be utilised. Instead, tools can be used to select and aggregate data into a more meaningful form which can be digested and then build knowledge.

The optimum way to present the information may depend on the receiver; the information that a risk analyst, a board member, an on-site worker or a regulator need will be different (Figure 5). If the analysis is presented in a report, a choice is made on who the target audience is. However, digitalisation helps satisfy a wider range, if not all parties. The goal is to present the data, or to allow the user to easily extract the data, in a way that enables them to become more informed in their area of interest. Too much information means that they will take longer to acquire knowledge and develop intelligence. Too little information means that they may not have enough to answer their questions or, worse, they draw the wrong conclusions.

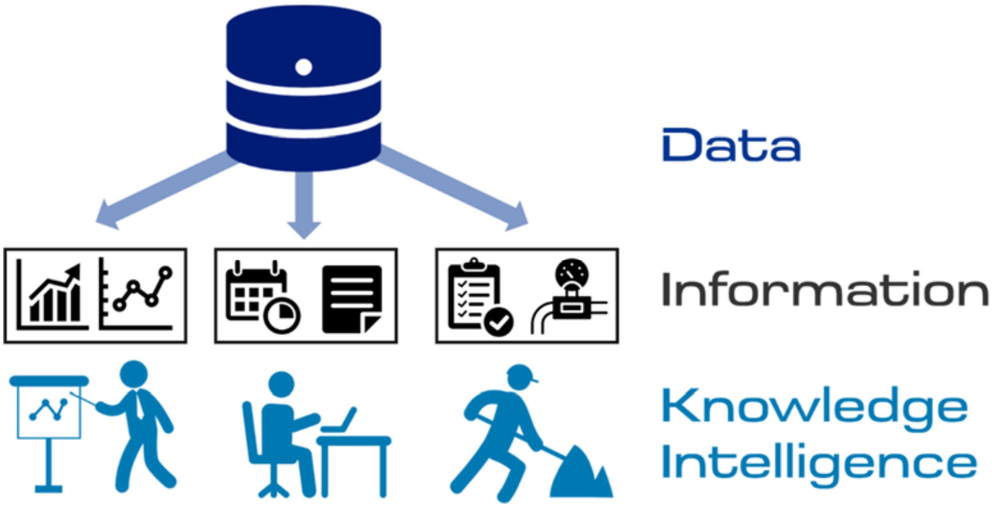

Figure 5 – Alternative Views of the Data for Different Readers

Information can be presented in various formats to reflect the underlying data. Time spent transforming the data into a more readily understandable format may be repaid by the target audience acquiring knowledge from it faster. We can envisage a hierarchy as follows:

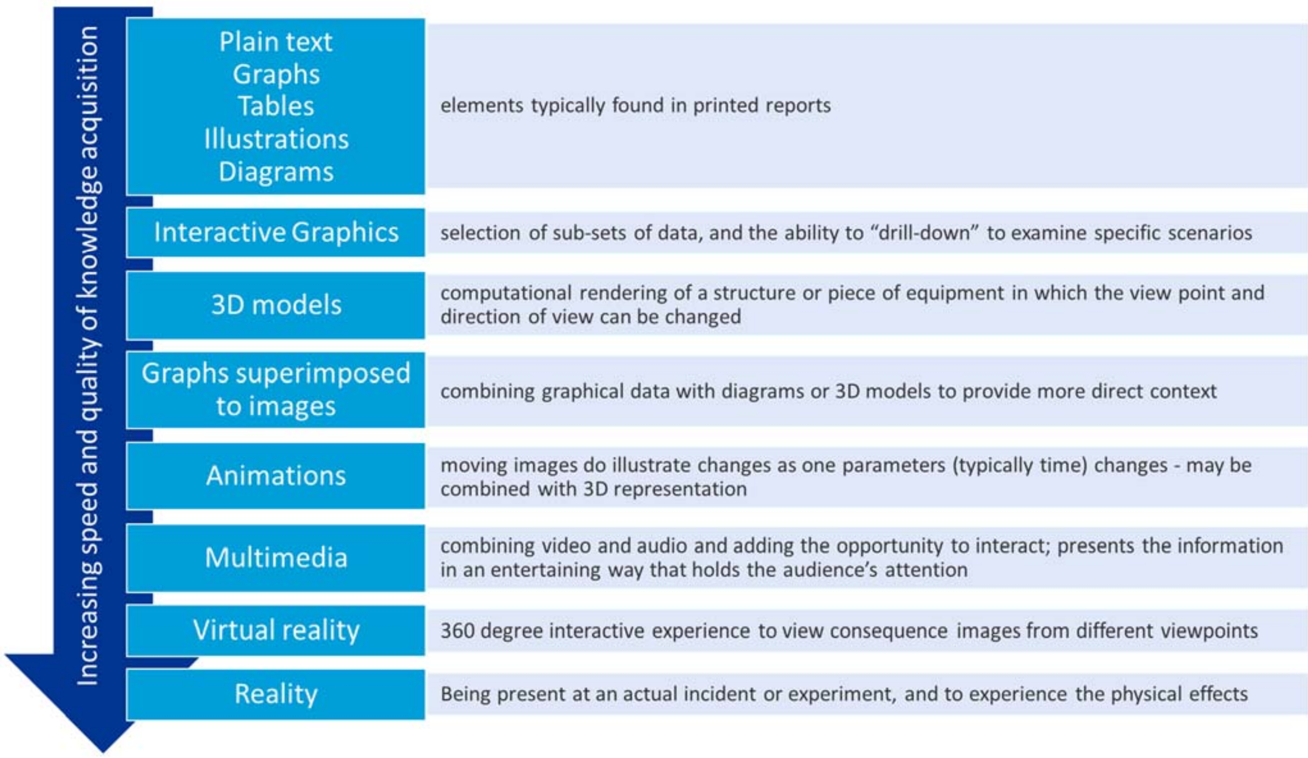

Figure 6 – Hierarchy of Data Understanding by Presentation Format

TECHNIQUES TO ENHANCE RISK COMMUNICATION

DNV GL has explored different options for how to best unlock the information contained within a risk assessment. The goal is to provide access to all the low-level data that may be needed to answer a potential future question, but also provide summaries across the data for higher-level consumption and to demonstrate trends or key implications of the analysis.

Many new tools regarding data analytics are available, such as Microsoft Power BI, Tableau, TIBCP Spotfire and many others. The goal of these products is to provide connections to and analytics across a variety of data sets. Each provide reports and dashboards that are compiled from the background data to assist the user or viewer in understanding the data relationships and trends. DNV GL has applied Microsoft Power BI to risk assessment datasets to assist with communication of the results. The following examples are a demonstration of this capability on a generic imaginary facility.

The risk assessment datasets contain the lowest level of risk outputs from the risk model – these datasets may extend to thousands or millions of records, depending on the facility size. Figure 7 presents a sample of a raw risk assessment dataset. Normally this data would be summarised and presented in a more digestible form as in Table 1. Although Table 1 gives the breakdown of risk contribution by scenario, the reader would not be able to determine the potential contribution by weather, or wind direction or outcome type, that is contained within the raw data, in Figure 7.

Run Row Name	Model Name	Outcome Key	Outcome Frequency [/yr]	Fatality Probability	Area	Building	PopCategory	Category N	Category PLL [/yr]	Total N	Weather Name	Weather Direction deg.	Outcome Code String	Time Step	Time [s]
Process Unit Day	IS1-Propane-L	1344	2.49E-06	1	'Population Grid'	'Outdoor'	'Operator'	2.83E-07	7.05E-13	2.83E-07	'Day Weathers\D 5m/s'	11.25 - 33.75	Continuous release No rainou	0	0.0
Process Unit Day	IS1-Propane-L	1345	2.49E-06	1	'Population Grid'	'Outdoor'	'Operator'	8.45E-05	2.11E-10	8.45E-05	'Day Weathers\D 5m/s'	33.75 - 56.25	Continuous release No rainou	0	0.0
Process Unit Day	IS1-Propane-L	1346	2.49E-06	1	'Population Grid'	'Outdoor'	'Operator'	1.31E-04	3.26E-10	1.31E-04	'Day Weathers\D 5m/s'	56.25 - 78.75	Continuous release No rainou	0	0.0
Process Unit Day	IS1-Propane-L	1347	2.49E-06	1	'Population Grid'	'Outdoor'	'Operator'	5.37E-06	1.34E-11	5.37E-06	'Day Weathers\D 5m/s'	78.75 - 101.25	Continuous release No rainou	0	0.0
Process Unit Day	IS1-Propane-L	1349	2.49E-06	1	'Population Grid'	'Outdoor'	'Public'	6.27E-05	1.56E-10	6.27E-05	'Day Weathers\D 5m/s'	123.75 - 146.25	Continuous release No rainou	0	0.0
Process Unit Day	IS1-Propane-L	1350	2.49E-06	1	'Population Grid'	'Outdoor'	'Public'	3.36E-02	8.36E-08	3.36E-02	'Day Weathers\D 5m/s'	146.25 - 168.75	Continuous release No rainou	0	0.0
Process Unit Day	IS1-Propane-L	1351	2.49E-06	1	'Population Grid'	'Indoor'	'Public'	2.26E-01	5.64E-07	5.43E-01	'Day Weathers\D 5m/s'	168.75 - 191.25	Continuous release No rainou	0	0.0
Process Unit Day	IS1-Propane-L	1351	2.49E-06	1	'Population Grid'	'Outdoor'	'Public'	3.22E-01	8.04E-07	5.43E-01	'Day Weathers\D 5m/s'	168.75 - 191.25	Continuous release No rainou	0	0.0
Process Unit Day	IS1-Propane-L	1352	2.49E-06	1	'Population Grid'	'Outdoor'	'Public'	1.05E+00	2.61E-06	2.64E+00	'Day Weathers\D 5m/s'	191.25 - 213.75	Continuous release No rainou	0	0.0
Process Unit Day	IS1-Propane-L	1352	2.49E-06	1	'Population Grid'	'Indoor'	'Public'	1.53E+00	3.97E-06	2.64E+00	'Day Weathers\D 5m/s'	191.25 - 213.75	Continuous release No rainou	0	0.0
Process Unit Day	IS1-Propane-L	1353	2.49E-06	1	'Population Grid'	'Outdoor'	'Public'	6.45E-01	1.61E-06	1.14E+01	'Day Weathers\D 5m/s'	213.75 - 236.25	Continuous release No rainou	0	0.0
Process Unit Day	IS1-Propane-L	1353	2.49E-06	1	'Population Grid'	'Indoor'	'Public'	7.33E-01	1.83E-06	1.14E+01	'Day Weathers\D 5m/s'	213.75 - 236.25	Continuous release No rainou	0	0.0
Process Unit Day	IS1-Propane-L	1353	2.49E-06	1	'Onsite'	'Building Set\Chemic	'Operator'	1.00E+01	2.43E-05	1.14E+01	'Day Weathers\D 5m/s'	213.75 - 236.25	Continuous release No rainou	0	0.0
Process Unit Day	IS1-Propane-L	1354	2.49E-06	1	'Population Grid'	'Indoor'	'Public'	1.32E-04	3.29E-10	1.01E+01	'Day Weathers\D 5m/s'	236.25 - 258.75	Continuous release No rainou	0	0.0
Process Unit Day	IS1-Propane-L	1354	2.49E-06	1	'Population Grid'	'Outdoor'	'Public'	1.18E-01	2.94E-07	1.01E+01	'Day Weathers\D 5m/s'	236.25 - 258.75	Continuous release No rainou	0	0.0
Process Unit Day	IS1-Propane-L	1354	2.49E-06	1	'Onsite'	'Building Set\Chemic	'Operator'	1.00E+01	2.43E-05	1.01E+01	'Day Weathers\D 5m/s'	236.25 - 258.75	Continuous release No rainou	0	0.0
Process Unit Day	IS1-Propane-L	1355	2.49E-06	1	'Population Grid'	'Outdoor'	'Public'	7.04E-03	1.75E-08	1.00E+01	'Day Weathers\D 5m/s'	258.75 - 281.25	Continuous release No rainou	0	0.0
Process Unit Day	IS1-Propane-L	1355	2.49E-06	1	'Onsite'	'Building Set\Chemic	'Operator'	1.00E+01	2.43E-05	1.00E+01	'Day Weathers\D 5m/s'	258.75 - 281.25	Continuous release No rainou	0	0.0
Process Unit Day	IS1-Propane-L	1356	2.49E-06	1	'Onsite'	'Building Set\Chemic	'Operator'	1.00E+01	2.43E-05	1.00E+01	'Day Weathers\D 5m/s'	281.25 - 303.75	Continuous release No rainou	0	0.0
Process Unit Day	IS1-Propane-L	1362	8.74E-08	0.463	'Onsite'	'Building Set\Chemic	'Maint'	4.63E+00	4.05E-07	1.39E+01	'Day Weathers\D 5m/s'	348.75 - 11.25	Continuous release No rainou	2	17.4
Process Unit Day	IS1-Propane-L	1362	8.74E-08	0.463	'Onsite'	'Building Set\Chemic	'Operator'	3.27E+00	8.10E-07	1.39E+01	'Day Weathers\D 5m/s'	348.75 - 11.25	Continuous release No rainou	2	17.4
Process Unit Day	IS1-Propane-L	1364	8.56E-08	0.463	'Onsite'	'Building Set\Chemic	'Maint'	4.63E+00	3.96E-07	1.39E+01	'Day Weathers\D 5m/s'	348.75 - 11.25	Continuous release No rainou	3	26.1
Process Unit Day	IS1-Propane-L	1364	8.56E-08	0.463	'Onsite'	'Building Set\Chemic	'Operator'	3.26E+00	7.93E-07	1.39E+01	'Day Weathers\D 5m/s'	348.75 - 11.25	Continuous release No rainou	3	26.1
Process Unit Day	IS1-Propane-L	1366	8.28E-08	0.463	'Onsite'	'Building Set\Chemic	'Maint'	4.63E+00	3.83E-07	1.39E+01	'Day Weathers\D 5m/s'	348.75 - 11.25	Continuous release No rainou	4	34.8

Figure 7 – Raw Risk Assessment Dataset Extract (Example data only)

Table 1 – Summarized Risk Result (Example data only)

Societal Risk Ranking Results	Risk Integral (/yr)	Risk Integral (%)	Average Outcome
IS5-Pentane-L	1.14E-02	34.16	5.98E+01
IS5-Pentane-R	9.03E-03	27.16	9.50E+01
IS4-Butane-L	2.18E-03	6.56	1.15E+01
IS4-Butane-R	2.15E-03	6.47	2.26E+01
IS1-Propane-R	2.08E-03	6.26	2.16E+01
IS1-Propane-L	1.33E-03	3.99	2.50E+00
IS2-Propane-L	1.17E-03	3.51	2.20E+00
IS3-Propane-L	1.11E-03	3.33	2.08E+00
IS2-Propane-R	1.01E-03	3.03	1.04E+01
IS3-Propane-R	7.54E-04	2.27	7.81E+00
IS4-Butane-M	2.14E-04	0.64	5.64E-01
IS5-Pentane-M	1.85E-04	0.56	1.95E-01
IS3-Propane-M	1.64E-04	0.49	2.66E-01
TF1b-Hexane-R	1.14E-04	0.34	2.86E+00
TF2-Octane-M	1.07E-04	0.32	1.33E-01
IS4-Butane-S	8.24E-05	0.25	2.17E-02
TF1a-Hexane-R	7.32E-05	0.22	1.83E+00
IS5-Pentane-S	6.35E-05	0.19	3.34E-02
All Other Scenarios	8.19E-05	0.25	-
TOTAL	**3.32E-02**	**100.00**	

Interactive Tables and Graphs

With tools like Power BI, the entire dataset is connected to a set of dashboards (designed and created by the risk professional). The resulting dashboard display of the dataset provides interactive filters and summary graphics, as in Figure 8. Many options are available for presenting the information; multiple configurations may be created and connected to the various data elements. As shown in the example, the relation of the risk result (PLL – potential loss of life) to the scenario, leak size, and impacted population are presented.

The data may be filtered by any of the fields within the dataset and made available for the user to adjust on demand. Based on the filter selection, the graphics' display updates. This approach allows access to the entire dataset but still in a summarized form, and completely controllable by the user. The graphics are also interactive in that by hovering over an element, the interface presents further information to assist the user in understanding it, as shown in Figure 9.

This approach allows any user access to the lowest element of the risk results and also in a summarized form; but the user should still understand the implications of these results and what they mean. It is advantageous for the user to have a foundation of knowledge of what the risk elements are – societal risk and individual risk, for example prior to viewing the information.

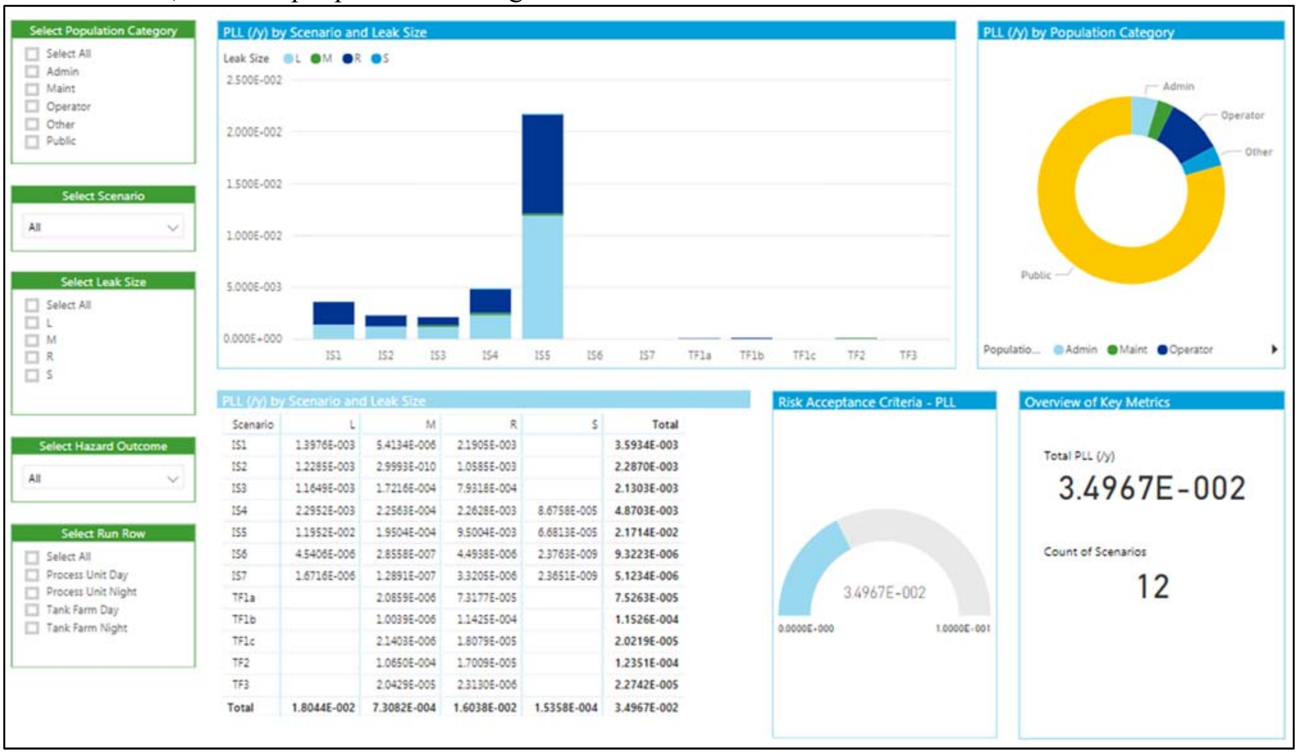

Figure 8 – Dashboard of Risk Assessment Dataset (Example only)

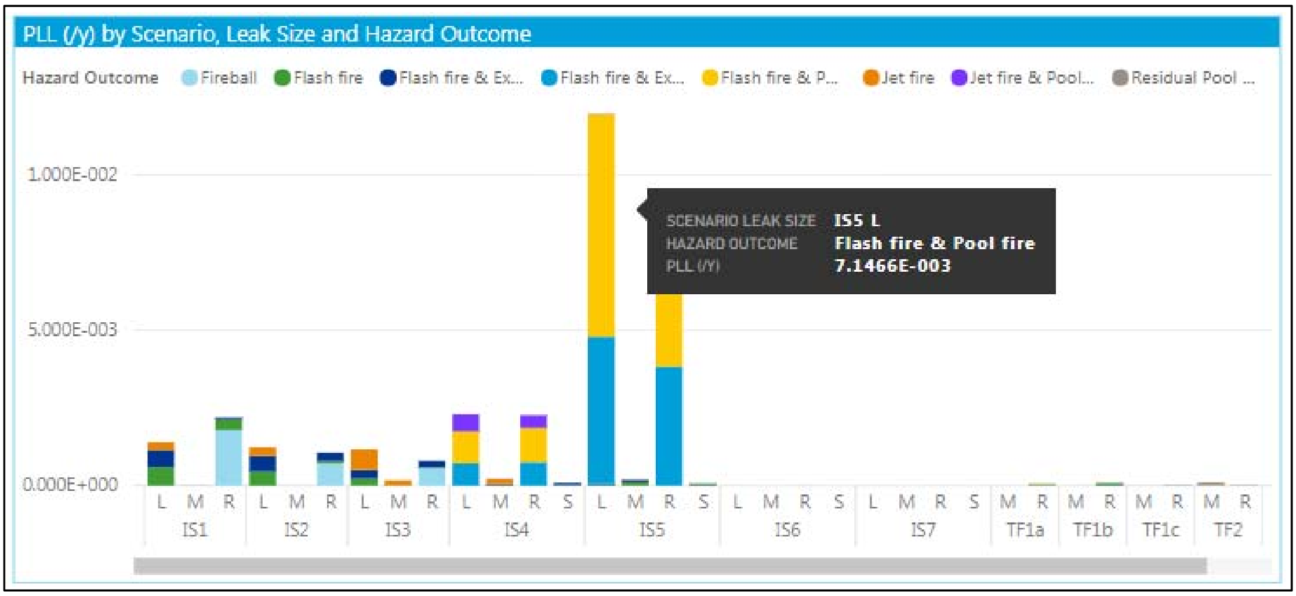

Figure 9 – Interactive Display Example

Figure 10 presents an example PLL result by impact to population groups. In Figure 10A, it is shown that public populations are the dominant group exposed to accidental scenarios. A user may want to understand which events are causing this impact and, by selecting the Medium (M) and Small (S) leak sizes from the filter set on the left, the graphics immediately update (Figure 10B). The exposure to the public population groups from these more frequent yet localized hazards is minimal compared to the exposure of the onsite population groups. So, it can be concluded that it is the large and rupture releases that impact the public. In this example case, there are large public populations close to the facility, and these can be affected by events large enough to impact beyond the facility perimeter.

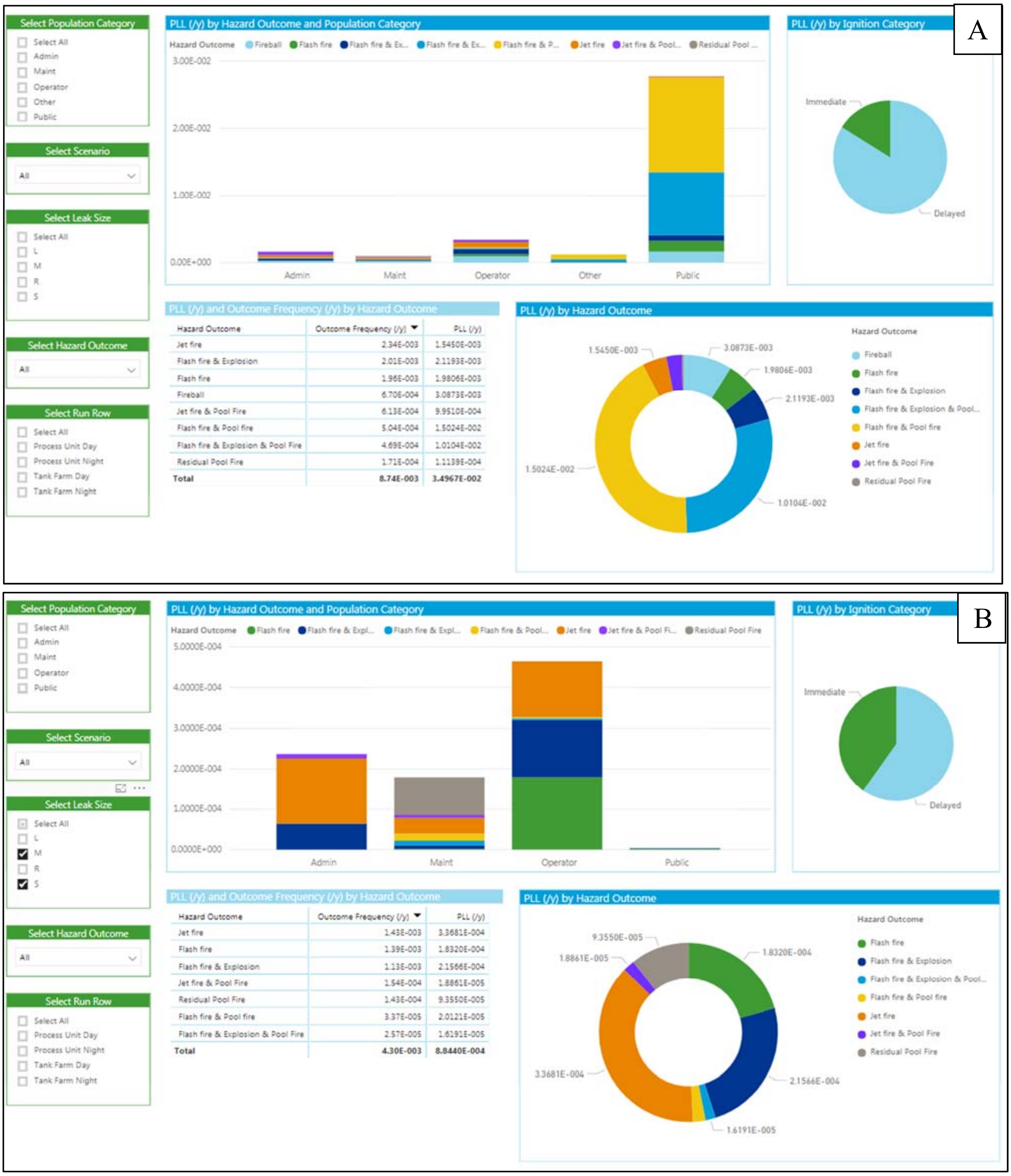

Figure 10 – Example Dashboard of PLL by Hazard Outcome A) no filters applied – summary of all risk data B) filter applied to leak size of M (medium) and S (small)

Obviously quantitative risk studies produce a large amount of data for consumption. However, qualitative risk studies – such as process hazard analyses (PHAs), HAZIDs or HAZOPs – can also produce a large amount of information, with many pages of logs from the review sessions. Similar types of dashboards can be created to summarize the log sheets and actions, see Figure 11. These allow quick filtering of the scenarios, safeguards, and/or recommendations – which can be very useful for large PHA studies.

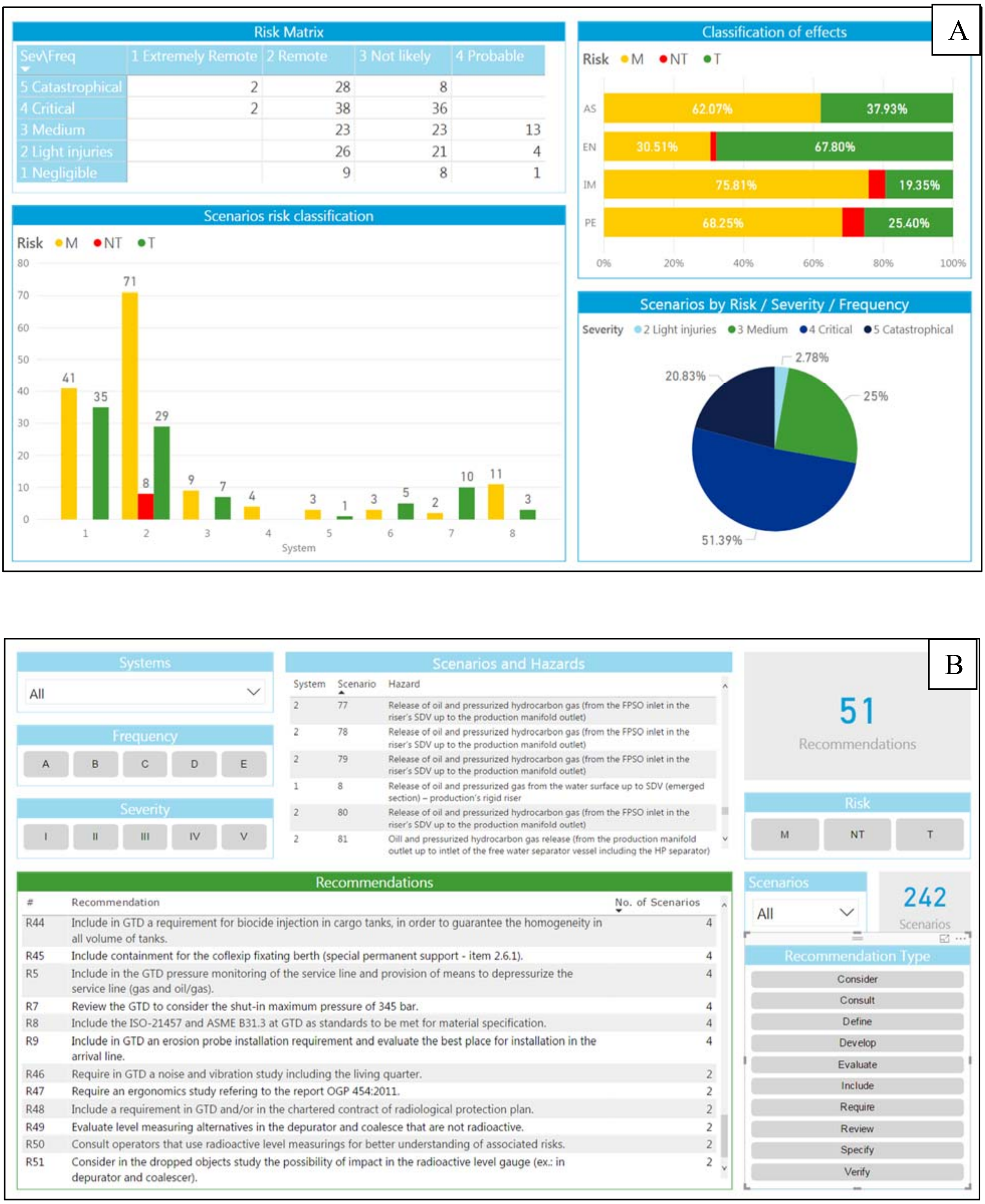

Figure 11 – Example Dashboard of HAZOP A) Risk Matrix Overview B) Recommendation Overview (Example Only)

Location-Specific Results and 3D Models

Another common aspect of onshore risk analysis is the display of location specific individual risk contours. The risk contours are often presented over a static 2D aerial image. Displays of the risk contours over interactive maps facilitates the user to zoom in and around the particular locations of interest, and also filter display of contours, population outlines, etc. (Figure 12). Additional features such as “bird views” that give a clearer 3D aspect to the view of the contours can also be useful, as shown in Figure 13.

The interactive tables and graphs are a step forward in providing the user with the ability to interrogate the results. However, connecting the data to the location or physical area provides even greater understanding. An example is given in Figure 14 for an example offshore facility, where the leak frequency data has been connected to an interactive 3D model of the facility. Power BI dashboards are still used to present the summarized data, but the dashboards are also connected to the 3D display. Filter selections in the dashboard are reflected in the offshore model display. These graphical displays allow stronger connections to be made between risk elements and their geometrical or location relationship.

Figure 12 – Example Individual Risk Contour Overlaid onto Aerial Map

Figure 13 – Example Individual Risk Contour Overlaid onto Aerial Map with Bird View

Sensitivity Capabilities

Once a risk analysis has been performed, there is usually a requirement to change some of the inputs to understand the resulting change in the risk picture. Often conditions change from the original study case and inputs need to be updated, but the user wants to understand the difference from the original case. Digitalization allows sensitivity studies to be viewed directly. Results can be selected and compared directly, as shown in Figure 15. Visual comparisons across the sensitivity cases facilitate the user to form associations between input alterations and the risk picture, fostering their greater understanding.

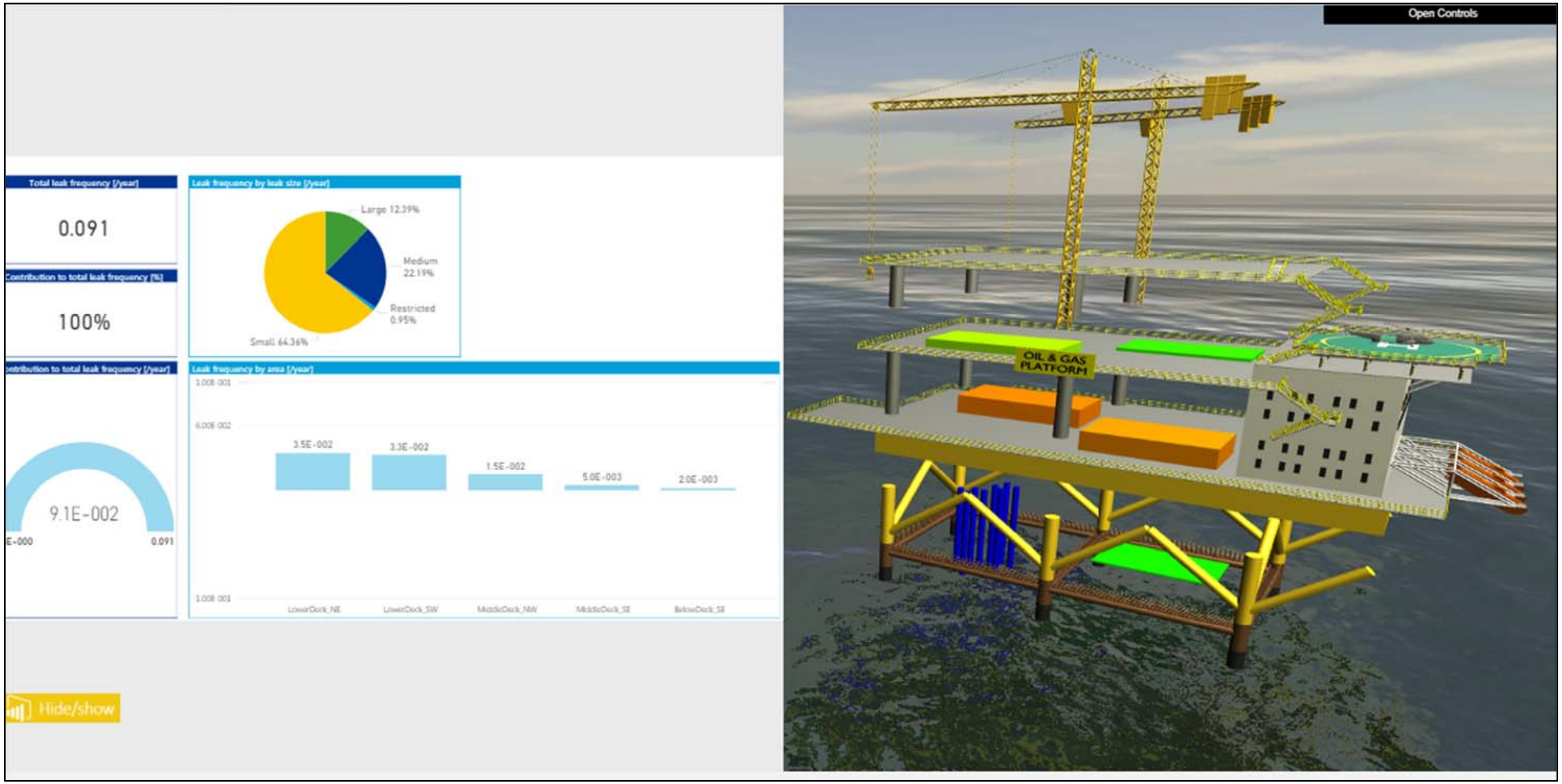

Figure 14 – Example Dashboard of Leak Frequency by Offshore Area Connected to 3D Model

Figure 15 – Example Dashboard of Sensitivity Comparison

Animations

Process safety risk analyses evaluate the consequences posed by a range of hazards materialising. Often these are reported as tables of hazard zone distances, or as 2D plots of the hazard. Animations of the consequence provide greater context for visualizing the potential impact of the fire hazard. Figure 16 presents two images from an example animation of a 3D fire representation at different time steps.

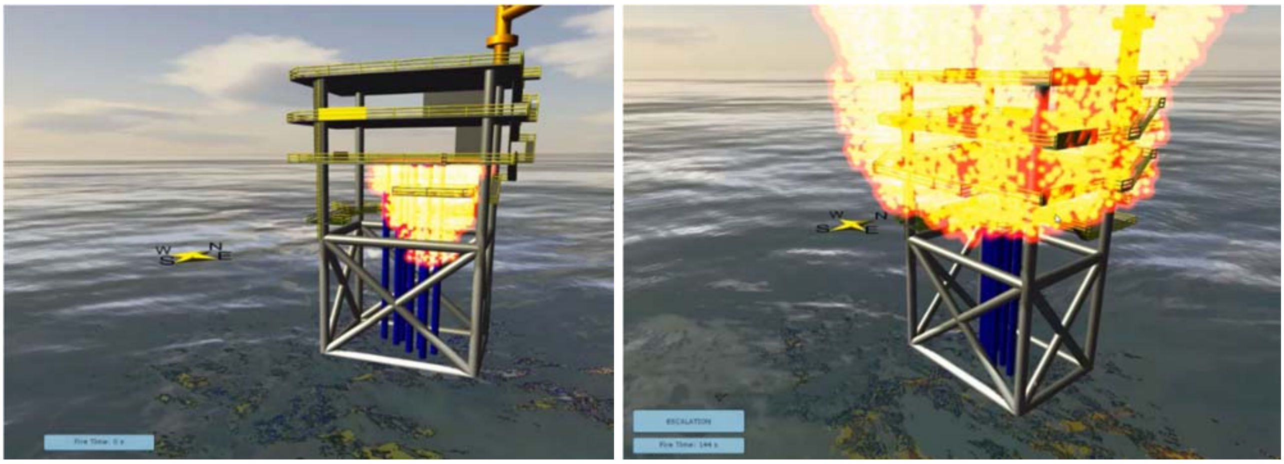

Figure 16 – Animated Simulation of Fire at different Time Steps

CONCLUSIONS AND FUTURE STEPS

The question posed in this paper is whether or not the technology now available can aid the oil and gas industry in developing its risk intelligence. There is a three stage process; data to information, information to knowledge and knowledge to intelligence. The assimilation of knowledge and combining it to produce intelligence are within the realm of the reader rather than the technology domain. However, the risk analyst can aim to provide the information in a form which meets the goals outlined in this paper (Figure 4). This is where modern computational tools can assist, i.e. in the transformation of data into information.

A number of methods are presented which show how it is no longer necessary to compromise between the information being complete and detailed versus it being compact and easy to digest. Various approaches can be employed in presenting the data in context and allowing it to be interrogated to yield specific information that is of interest to a particular reader. The audience can customise the view of the data to each of their own requirements and perspective. They no longer need to specify the structure and content in advance. This is a means to an end; well presented information allows the audience to construct their knowledge more quickly and completely. From this they can build intelligence and ultimately make more effective decisions.

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