

Steps towards a ‘Living’ QRA and Instant Risk-based Decision-Making

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Quantitative Risk Assessments (QRAs) were originally developed to determine compliance by comparing aggregated risk numbers with tolerability criteria. Typically, QRA specialists collect information which describes an asset to construct a digitised model including numerous simulations of accident scenarios. The output of such studies are usually static reports providing an overview of the detailed work undertaken and a high-level summary of the results against applicable tolerability criteria. Increasingly operators are using the QRA model to assist with risk-based decision making; traditionally, that has required additional assessments to be carried out, generally by the QRA analysts who conducted the original studies.

DNV GL has a range of models, experimental data and rulesets that are brought together in integrated QRA tools that are used to produce the reports required by operators. In response to the changing digital landscape, DNV GL has created “Cloud QRA”: an online QRA service, hosted on a cloud server, that changes the QRA, from being a static set of results, to a “living QRA” which can be updated throughout an installation’s lifecycle. This is aligned with the movement of the industry towards the concept of a “digital twin” and has significant benefits.

This paper demonstrates how online applications such as Cloud QRA can be used to turn the traditional process into a dynamic QRA which can be updated throughout the lifecycle of a facility. The purpose of this QRA service is to encourage the workforce, both operators and designers, to interrogate the results down to fundamental levels using interactive dashboards on Microsoft Power BI and make more informed decisions.

In addition, DNV GL has used the latest internet technology to develop 2D and 3D graphics that also run in a web browser and can be combined with the QRA to extract more detail than previously possible and communicate risks in new ways. This allows users to determine risk drivers, isolate single events and filter results to understand risks to a greater depth than is possible through a paper report and allow a greater understanding of their hazards.

Keywords: Digitalisation, Cloud QRA, hazard management, Power BI, Digital Twin

Introduction

Quantitative Risk Assessments (QRAs) were originally developed to determine compliance by comparing aggregated risk numbers with tolerability criteria. Typically, QRA specialists collect information which describes many aspects of an asset to construct a basic “digital twin” including numerous simulations of accident scenarios (see Figure 1). The output of such studies are usually static reports providing an overview of the detailed work undertaken and a high-level summary of the results against applicable tolerability criteria. Increasingly operators are using the QRA model to assist with risk-based decision making; traditionally, that has required additional assessments to be carried out, generally by the QRA analysts who conducted the original studies.

DNV GL has a range of models, experimental data and rulesets that are brought together in integrated QRA tools that are used to produce the reports required by operators. In response to the changing digital landscape, DNV GL has created “Cloud QRA”: an online QRA service, hosted on a cloud server, that changes the QRA, from being a static set of results, to a “living QRA” which can be updated throughout an installation’s lifecycle. Using the DNV GL QRA data structure built on Microsoft Azure cloud service allows the use of user authentication and security systems that have been developed alongside the management of user roles. This allows DNV GL, or any third party that requires use of the tool, strictly controlled access to this “digital twin” of the installation.

This paper considers each stage of the process depicted in Figure 1 and demonstrates how online applications can be used to turn the traditional QRA process into a dynamic QRA which can be updated throughout the lifecycle of a facility. This living QRA can be used as a tool to engage the workforce and allow a greater understanding of their hazards.

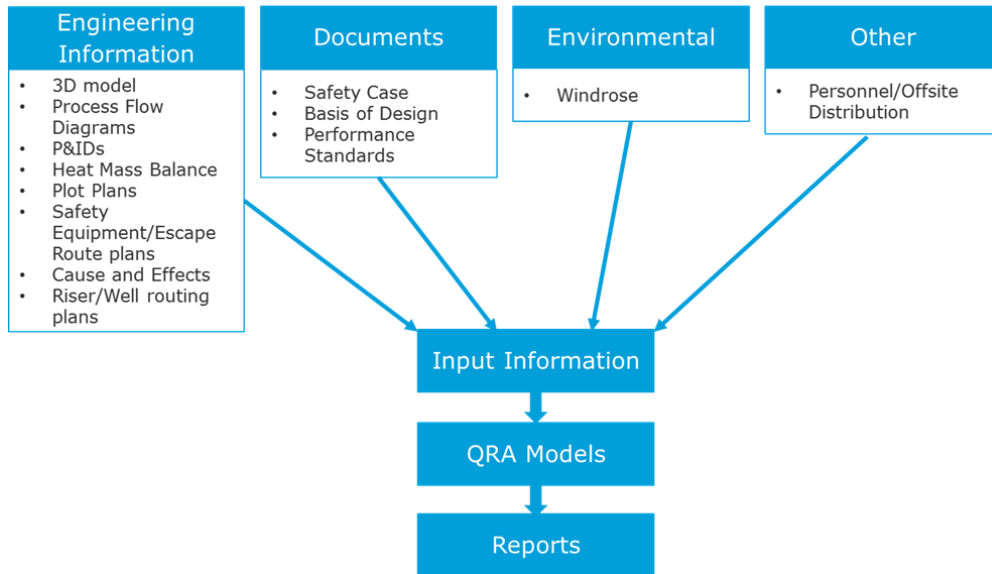


Figure 1: Simplified QRA Process

Key Innovations and Structure

The structure of Cloud QRA is listed below along with a brief summary of the key benefits of each element of the structure:

- Database – stores the asset data in a structured and consistent format and gives instant access to the full QRA lifecycle history for an asset and cross asset views.
- Cloud environment – superior flexibility in user access, speed of deployment of enhancements and for models, significant computational scaling capability.
- 2D/3D graphical reporting – displays visual representation of data to generate an increased understanding and provide clear indication of the impact of incidents on locations across the asset for non-experts.
- Power BI reporting – allows data to be displayed and interrogated in a variety of formats and customised depending on the requirements of the project.

The concept of storing data that describes an asset centrally, reading this data into models which perform specific analyses, and then summarising this data in tabular or visual representations is not new. However, the means in which this is delivered through the use of leading web technology provides a blueprint for the “digital twin” future.

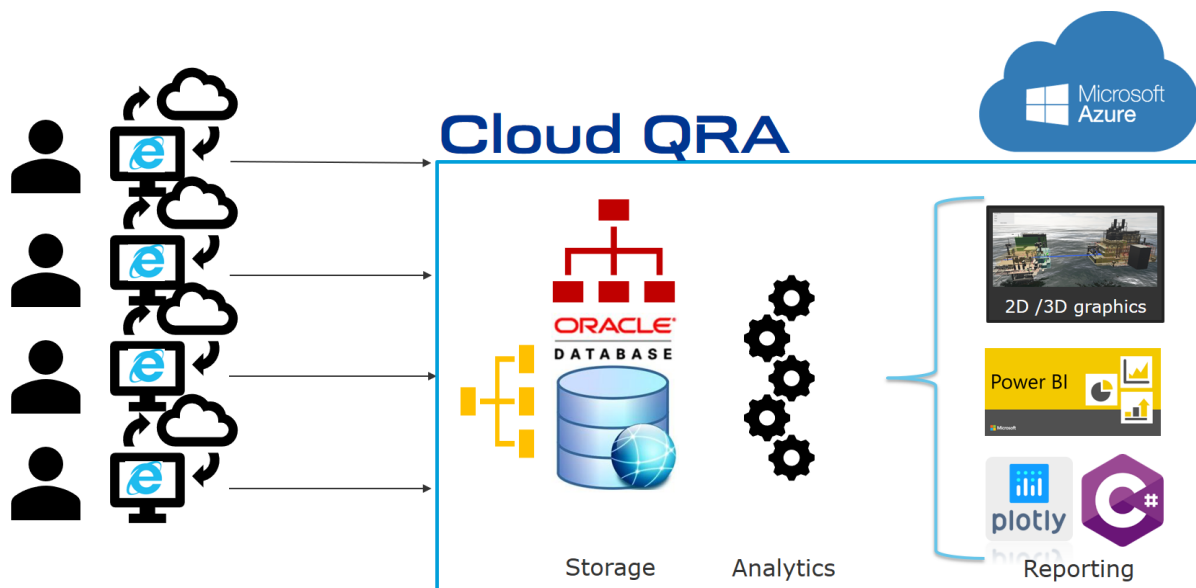


Figure 2: Structure of Cloud QRA

Input Information

Traditionally, input data for the QRA is gathered manually from various sources such as paper/PDF engineering drawings and spreadsheets. In order to define the layout of the facility, this is often done by mapping equipment/points and recording the data in the form of X, Y, Z co-ordinates. This can be difficult to visualise and is subject to human error such that the typical geometrical aspects required in the QRA (e.g. release locations, escape routes, etc) could be defined erroneously. Aside from direct data ingestion from 3D computer aided design (CAD) models, DNV GL are using recent advances in internet technology to develop a visual tool such that electronic plot plans may be marked-up electronically. The 2D layouts are used to mark-up modules and buildings as well as release locations, safety equipment such as lifeboats and liferafts, and escape routes. An example of this is given in Figure 3. This 2D layout information can then be linked to a 3D representation of the facility, constructed by importing PDMS models into the tool. The analyst may also use data-capture tables to import platform-specific data directly from spreadsheets that detail Heat & Material balance, Major Equipment information, wind rose and other information.

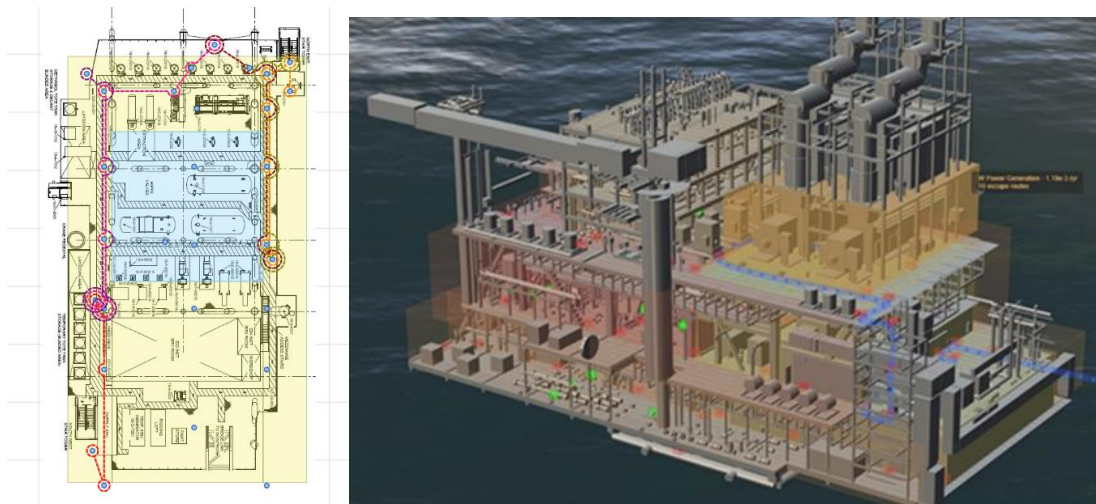


Figure 3: Example 2D and 3D plots with modules, installation locations and escape routes marked on.

A key driver of the QRA is the leak frequency associated with isolatable systems. These leak frequencies are generated by combining platform-specific equipment counts with historical generic leak frequency data from sources such as the UK HSE HCR database or the PARLOC pipeline database.

Traditionally, PFDs, P&IDs are marked-up and highlighted manually or electronically to illustrate an isolatable system. This highlighted information is then read off by the user to produce the equipment count. These activities are often inefficient and are a time-consuming process.

However, many of the original electronic engineering design documents and models, such as process flow diagrams (PFDs), piping and instrument diagrams (P&IDs) and 3D models are constructed using electronic CAD drawings which contain intelligent data. DNV GL have developed a new Automated Data Extraction (ADE) software tool to assist in extracting this intelligent data and converting it into useful QRA input data such as a parts count for use in calculating leak frequencies, or positional information for equipment. This level of automation allows studies to be updated automatically with the added benefits of reducing or even eliminating the potential for errors from the process and ensuring that a consistent methodology was applied to frequency analysis. This is discussed further in Coates 2018 and Cheung 2019.

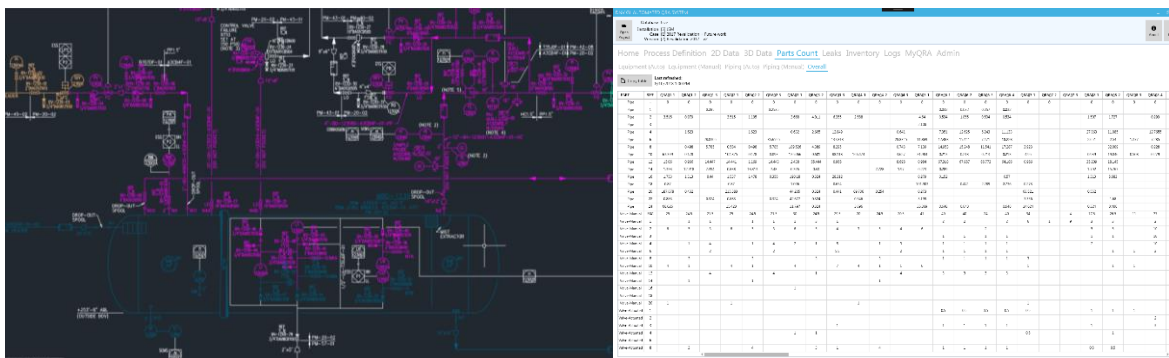


Figure 4: Marked up P&ID/Component table

Data Storage and QRA Models

The Azure cloud data storage platform has been designed by DNV GL to retain all of the input data in structured hierarchies relating to the physical locations of the installation and the segmentation of the process plant. This storage format therefore

provides a flexible means of describing the asset (e.g. a “digital twin”) where the structured hierarchies determine inheritance of information. An example of this may be the windrose which filters through to all locations on the asset or a fire detection reliability which feeds into the modelling of all release scenarios in that location.

Currently, the input data is used in conjunction with the DNV GL offshore consequence and risk models running on the cloud to generate the results required and this feeds back into the structured cloud database ready for reporting.

This hierarchical data structure provides flexibility in the software; changes to inputs, modelling or reporting can be undertaken without significant impact to the core components of user interface, storage, modelling or reporting. Thus ensuring that previously run models are unaffected. This allows for progressive advances in the complexity of the software.

It is considered that this structured approach could also be extended to allow other external models, e.g. computational fluid dynamics models (CFD) or look-up tables to be used as alternatives to the DNV GL offshore consequence and risk models.

In addition, by storing all inputs and outputs centrally there is the possibility in identifying trends in data which could be used to determine reference cases for early concept studies, therefore negating the need for detailed modelling.

Reports

DNV GL has been using Power BI to display the aggregated QRA results in Cloud QRA. Power BI can be linked directly to the QRA database and essentially provides a meaningful snapshot of the asset, consequence and risk data that can be interrogated down to fundamental levels. In this way, risk drivers can be understood in an easy to use graphical format. The flexibility in Power BI means that data can be displayed in a variety of formats. Customisation of output is relatively straightforward on the Power BI dashboard and if necessary, the alternative output templates developed depending on the requirements of the project.

In addition, internet technology (e.g. JavaScript libraries) can be used to display visual representation of data to generate an increased understanding, for example, contour plots to understand where hazards are concentrated. These can be written to take slices of data from the database.

However, it is recognised that presenting QRA data in a tabular format has its benefits and so results can be presented in a number of ways to benefit the communication of risk levels to the user and aid the screening process. All tabular results can be exported to spreadsheet in a straightforward way and additional output customised to suit project needs.

These aspects are indicative of the benefit of a structured database approach in that the reporting then becomes more rapidly customisable, and its presentation is shaped by the needs of the user.

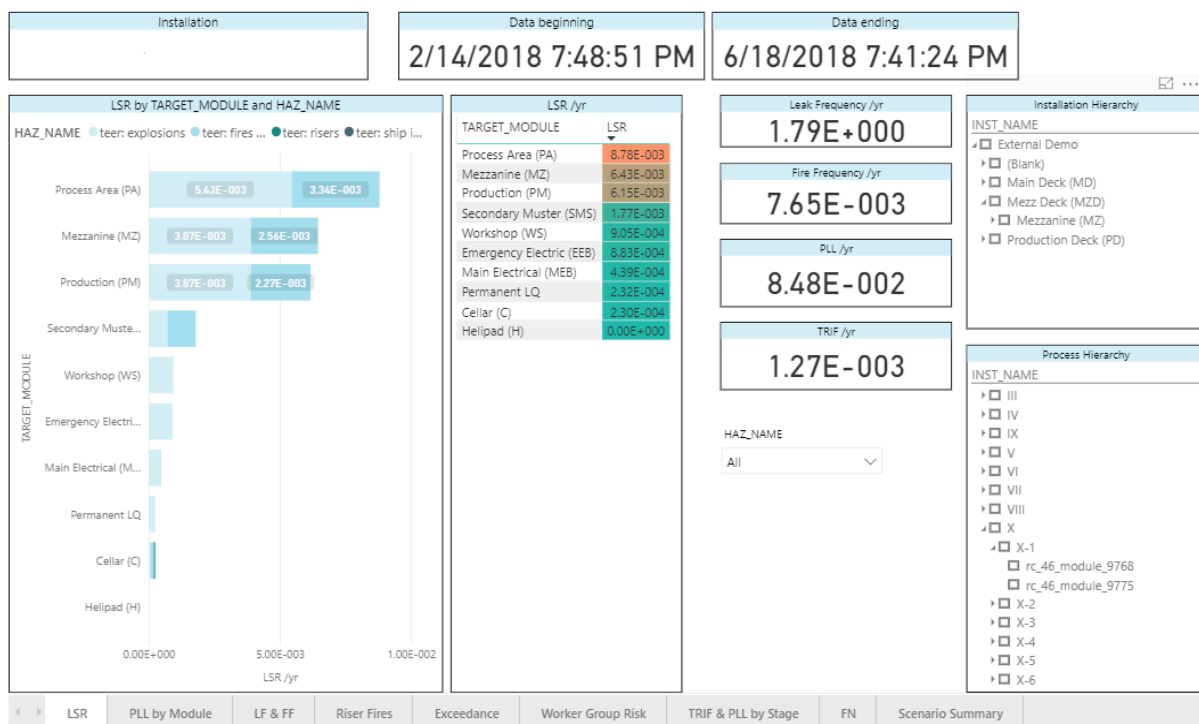


Figure 5: Power BI Interactive Dashboard - Graphical

Scenario Summary										
ISO_NAME	CASE_NAME	FUEL_TYPE	MOD_NAME	PRESSURE	INVENTORY_M	LEAK_FREQ	FIRE_FREQ	Max of FREQ	PLL	TRIF
X	X-1	Natural Gas	Production (PM)	68	3.15	1.98E-002	1.00E-004	1.72E-002	1.84E-005	
X	X-1	Natural Gas	Process Area (PA)	68	3.15	1.98E-002	1.00E-004	1.70E-002	1.18E-005	
XI	XI-3	Natural Gas	Process Area (PA)	126	0.90	1.67E-002	1.29E-004	1.32E-003	7.42E-005	
IX	IX-13	Natural Gas	Process Area (PA)	69	2.20	1.67E-002	1.29E-004	1.24E-003	7.09E-005	
IX	IX-11	Natural Gas	Process Area (PA)	33	3.70	1.60E-002	1.59E-004	1.22E-003	1.73E-005	
IX	IX-14	Natural Gas	Process Area (PA)	68	1.50	1.49E-002	1.30E-004	1.20E-003	1.73E-005	
XI	XI-1	Natural Gas	Process Area (PA)	66	0.90	1.630E-002	1.21E-004	1.17E-003	6.54E-005	
XIV	XIV-1	Natural Gas	Production (PM)	239	16.40	1.45E-002	1.58E-004	9.20E-004	1.74E-005	
IX	IX-10	Natural Gas	Process Area (PA)	33	3.30	1.67E-002	1.29E-004	9.13E-004	2.11E-005	
XII	XII-2	Natural Gas	Process Area (PA)	125	0.20	1.58E-002	1.20E-004	6.48E-004	1.50E-005	
XI	XI-4	Natural Gas	Process Area (PA)	125	0.90	1.09E-002	1.70E-004	5.84E-004	1.23E-005	
X	X-4	Natural Gas	Process Area (PA)	66	3.28	1.09E-002	1.21E-004	5.02E-004	1.98E-005	
XII	XII-1	Natural Gas	Production (PM)	125	0.20	1.920E-003	1.77E-005	4.01E-004	1.68E-005	
XII	XII-4	Natural Gas	Process Area (PA)	125	0.20	1.40E-002	1.16E-004	3.98E-004	1.80E-006	
XI	XI-2	Natural Gas	Process Area (PA)	66	0.90	1.43E-002	1.21E-005	3.73E-004	1.09E-005	
IX	IX-8	Natural Gas	Process Area (PA)	10	7.10	1.80E-002	1.31E-004	3.63E-004	1.14E-005	
XII	XII-3	Natural Gas	Process Area (PA)	125	0.20	1.62E-002	1.14E-004	3.38E-004	1.75E-006	
XVIII	XVIII-2	Natural Gas	Production (PM)	34	55.80	1.61E-002	1.09E-005	3.37E-004	1.98E-006	
XVIII	XVIII-3	Natural Gas	Production (PM)	34	55.80	1.61E-002	1.09E-005	3.37E-004	1.98E-006	
IX	IX-7	Natural Gas	Process Area (PA)	11	7.60	1.67E-002	1.70E-004	3.19E-004	1.77E-005	
IX	IX-12	Natural Gas	Production (PA)	33	3.70	1.43E-002	1.49E-005	2.75E-004	1.06E-005	
XVII	XVII-1	Natural Gas	Process Area (PA)	291	0.20	1.16E-003	1.48E-005	2.69E-004	1.49E-005	
XVII	XVII-1	Natural Gas	Process Area (PA)	291	0.20	1.16E-003	1.48E-005	2.69E-004	1.49E-005	
XVIII	XVIII-1	Natural Gas	Production (PM)	34	55.80	1.87E-002	1.67E-005	2.69E-004	1.39E-006	
XII	XII-1	Natural Gas	Process Area (PA)	125	0.20	1.920E-003	1.77E-005	2.59E-004	1.62E-006	
X	X-5	Natural Gas	Production (PM)	125	0.76	1.698E-003	1.67E-005	2.43E-004	1.28E-005	
X	X-3	Natural Gas	Production (PM)	125	0.96	1.698E-003	1.67E-005	2.32E-004	1.73E-005	
X	X-6	Natural Gas	Production (PM)	76	2.16	1.698E-003	1.34E-005	1.05E-004	1.57E-006	
Total						1.79E+000	7.65E-003	8.48E-002	1.27E-003	

Figure 6: Power BI Interactive Dashboard- Tabular

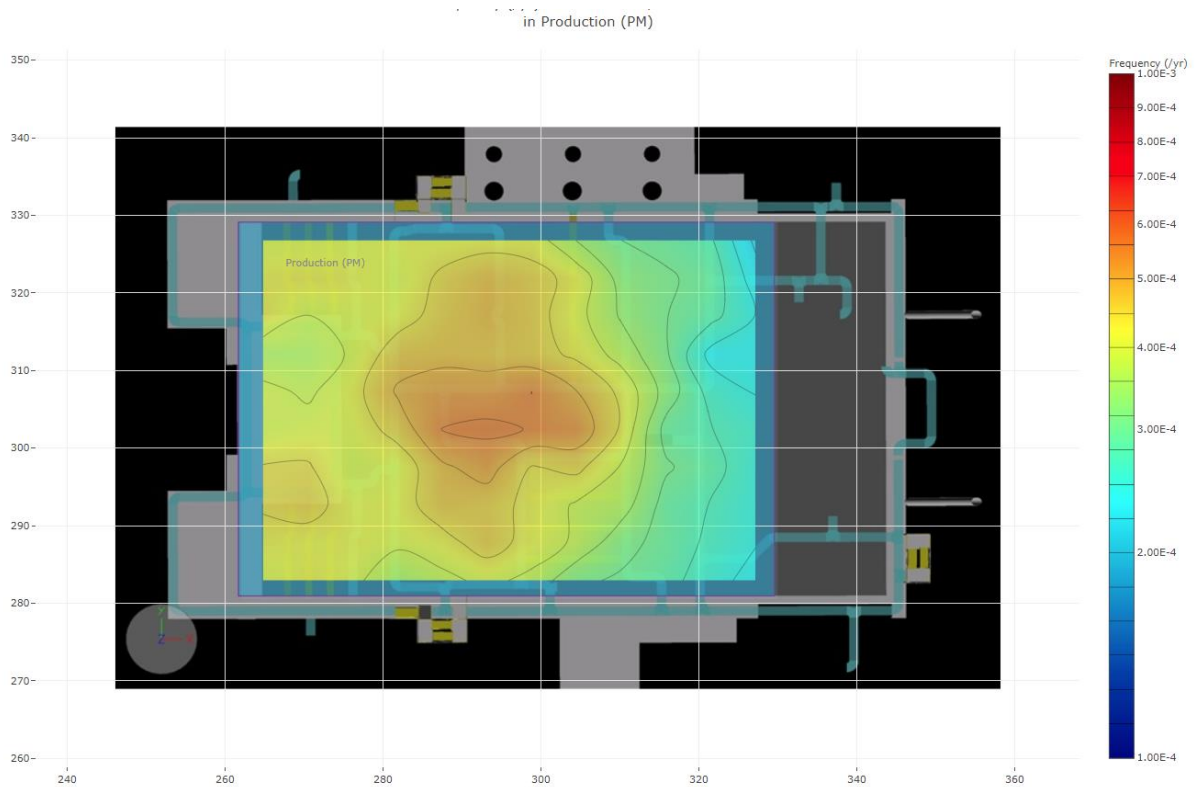


Figure 7: Example of JavaScript Visuals (Fire Exceedance Data)

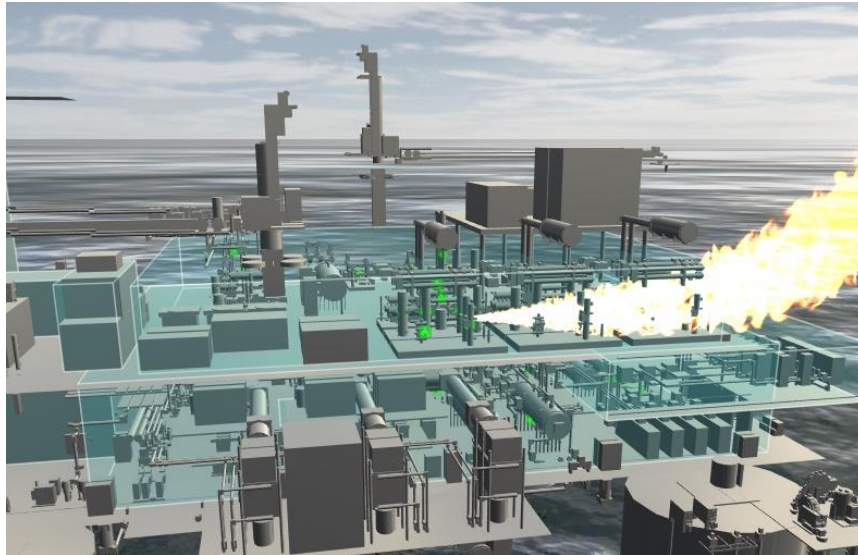


Figure 8: Example of JavaScript Visuals (Fire Consequence Data)

Case Study

By hosting all of these services online, it is possible for the QRA model to be shared by the risk analysts and the asset engineers. This permits sensitivity analysis to be performed by the asset engineers as well as the risk analysts.

An example of such a simple sensitivity is demonstrated below; the existing QRA considered the risk to personnel based on a shift rotation of 2 weeks on/3 weeks off for all worker groups. If the asset wishes to understand what the impact on risk is following changes in shift rotation; then the number of flights per worker group can be simply changed (see Figure 9) and the risk models re-run. The results dashboards can then be easily compared to see the impact in risk. Figure 10 shows summary results for a range of metrics for both cases and Figure 11 shows detailed results for personnel risk for both cases. In addition to generating graphical results, the asset engineer can also choose to show the results in tabular form (see Figure 12).

Home > Setup > Installation				
Monitor Points Escape Routes Wind Rose Manning TR Helicopter Lifeboats LiferafTs				
No. of Worker Groups: 3 Show Platform & Deck				
WORKER GROUPS (click to edit name)				
	Technical	Management	Services	Total POB
POB	45.0	8.0	9.0	62.00
Helicopter flights per year	11.0	11.0	11.0	
Occupancy	39.0%	40.0%	40.0%	
MODULE	MANNING (%)			
Accommodation	53.38	54.79	91.75	36.66
TR	20.05	40.41	8.25	13.00
Utilities	8.02	1.62	0.00	3.74
PA Upper	1.50	0.45	0.00	0.71
PA Lower	5.76	0.95	0.00	2.67
Wellbay	0.25	0.06	0.00	0.12
Process WD	5.51	0.57	0.00	2.53
Wellhead WD	2.26	0.16	0.00	1.03
Utilities WD	1.00	0.23	0.00	0.47

Figure 9: Shift Pattern Case Study: Input Screen for Changing Helicopter Pattern ((a) original, (b) modified)

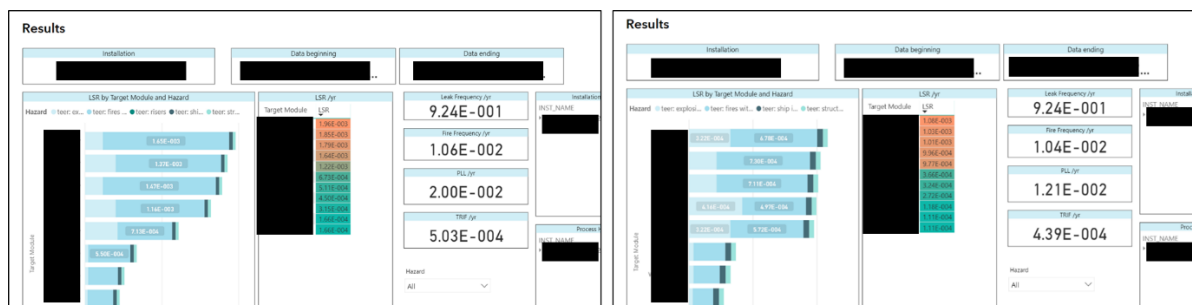


Figure 10: Shift Pattern Case Study: Summary Results ((a) original, (b) modified)

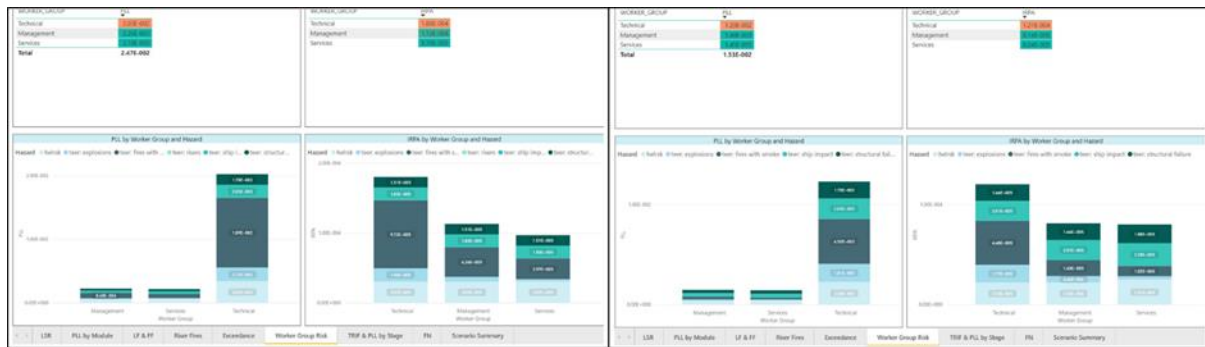


Figure 11: Shift Pattern Case Study: Personnel Risk Results ((a) original, (b) modified)

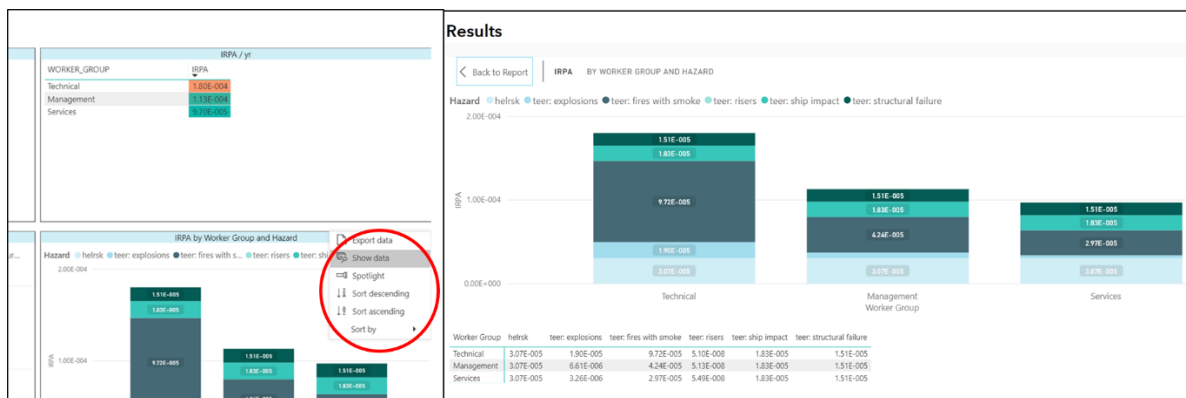


Figure 12: Shift Pattern Case Study: Viewing Personnel Risk Results in Tabular Form ((a) original, (b) modified)

Conclusions

Modern web-based tools such as Cloud QRA allow project stakeholders full access to the underlying data within their model such that data can be interrogated, and sensitivities can be run on any parameter. This provides significant benefit to perform ‘what if’ scenarios quickly, allowing timely and better-informed risk-based decisions which may shape the early stage of a design and avoid significant modification costs at a later stage. This type of application means it easier to identify the drivers behind risk changes through the project lifecycle, aiding concept selection and providing an auditable trail through to detailed design.

Cloud QRA is designed to be used to carry out a full QRA. This approach uses consequence models, either in the form of CFD or phenomenological modelling. These require significant input data and can be time consuming to run, in order to generate detailed results. Current work by DNV GL includes the development of a set of input screens that allow the user the option to use simplified models and look up tables to allow the analyst to quickly run the consequence assessment in order to perform risk screening for a range of design options.

Such a premise of holding all asset data centrally is closely linked to the concept of a “digital twin” where a model of an asset is used to undertake analyses quickly and in line with the current status of that asset. It is clear that this is the way in which the industry is moving and in time, one could see the QRA modelling being undertaken directly on an asset’s digital twin.

References

Coates, T., Golowczynski, M., Tomkins, J.E., Wattis, Z. E., Automated Use of Engineering Data within Risk-based Decision Making, Hazards 29, May 2019.

Cheung, D.P., Nair, S.R., Salter, J., Robinson, C. G., Wattis, Z.E., Risk-Based Decision-Making in Offshore Production Facilities Design Using Enhanced Application of QRA, 18th AIChE Spring Meeting and 14th Global Congress on Process Safety, April 2018.