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A review of experience from two offshore design projects

Prepared by
Amey Vectra Ltd
for the Health and Safety Executive

OFFSHORE TECHNOLOGY REPORT

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D Piper
Amey Vectra Ltd
Europa House
310 Europa Boulevard
Gemini Business Park
Westbrook
Warrington
WA5 7YQ

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St Clements House, 2-16 Colegate, Norwich NR3 1BQ

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Summary

This report describes the outcome of a review of experience from two recent offshore design projects, primarily from a safety perspective, to identify key issues and any lessons that may be learnt for future projects. In particular, the review provided an opportunity to compare experience from a UK project with that from a project carried out in the USA at approximately the same time. The review was also undertaken against the background of the report by Offshore Design Engineering Ltd (ODE), comparing UKCS and GoM practice [1]. Consideration was given to the extent to which the safety-related conclusions of the ODE report were supported by the experience of the two projects.

Background information is provided on the different regulatory regimes, together with specific details relating to the two projects. The overall approach to safety is discussed and statistics given on the amount of analysis undertaken on the two projects.

It is concluded that the differences identified by ODE were offset to a large extent by the influence of the Operating Company's corporate standards, which tended to be aligned with the UK safety regime. Therefore, the cost differentials identified in [1] were not particularly evident in the two projects discussed here.

1.0 INTRODUCTION

1.1 Background

In the present economic climate in the oil and gas industry, new projects typically are undertaken within ever shorter timescales, in order to achieve stringent financial targets (so-called 'fast-track' projects). In this environment, design decisions are of necessity taken quickly to maintain project schedules. Where such decisions have a safety implication or form part of an 'ALARP' argument, it is important to ensure that they are given adequate consideration and are documented appropriately. To identify and develop 'best practice' in this area, the UK Health & Safety Executive (HSE) is keen to learn from experiences of recent design projects, both in the UK and elsewhere.

However, this objective needs to be viewed in the context of the work of the Oil and Gas Industry Task Force (OGITF). The OGITF was formed jointly by government and industry in 1998 to develop strategies for reducing the cost base of UK oil and gas operations, and to examine and prioritise initiatives to improve the competitiveness of the UK industry. Under the auspices of the Competitiveness Working Group of the OGITF, a study was carried out last year by Offshore Design Engineering Ltd (ODE) to evaluate the differences between the UK Continental Shelf (UKCS) and the Gulf of Mexico (GoM) in relation to the design and construction of offshore topsides facilities. The ODE report [1] suggests that the goal-setting safety regime in the UK contributes to the increased cost of UK offshore facilities, when compared with the GoM.

In relation to safety, the ODE report concluded that there were three key differences between UK and GoM practice:

- Standardisation: the larger GoM market has led to off-the-shelf designs that follow prescriptive standards. Process packages and equipment are also standardised
- Simplification: layouts are generally simpler and designs more repetitive, giving rise to simplified safety analysis with a lower tendency to customise design
- Degree of analysis: whilst the 'goal-setting' safety regime in the UK was not found to be an underlying cause of any cost differential, it is suggested that the high levels of risk analysis implicit in current UK practice could be avoided and that the volume of Safety Case documentation could be reduced.

The aim of the present study therefore was to review the experience from two recent design projects, primarily from a safety perspective, to identify key issues and any lessons that may be learnt for future projects. In particular, the review provided an opportunity to compare experience from a UK project with that from a project carried out in the USA at approximately the same time.

This in turn allowed consideration of the extent to which the safety-related conclusions of the ODE report were supported by the experience of the two projects.

1.2 Objectives

The two principal objectives of the study were:

- To consider the approach adopted within the two projects with regard to technical safety, and compare experience
- To examine the extent to which the key differences identified in the ODE report in relation to safety (viz. standardisation, simplification, degree of analysis) were evident in the two projects.

1.3 Scope and Methodology

The study took the form of a review of experience from the FEED stage of two recent (1998-9) fast-track design projects in which Amey VECTRA (VECTRA) staff were involved and where the Operating Company was the same in both cases. The first project was carried out in the UK and was concerned with the design of a normally unattended installation (NUI) for the North Sea. A VECTRA consultant was employed by the Operator to provide specialist QRA and safety engineering support. The second project was undertaken in the USA and involved the design of a manned GoM-type platform. In this case, a VECTRA consultant was employed by the Operator as the Project Safety Assessor. The two projects are described in detail in Section 2 below.

The overall structure of the report was developed following a “brain-storming” exercise to identify the key issues. These were then expanded under each of the main headings, using relevant source documents. To enhance the value of the review in relation to the findings of the ODE report, additional general information on GoM projects was identified for inclusion.

In addition, the Operator was asked to provide technical input to the review, in particular with regard to the use of the risk assessment package. It is argued that this does not detract from the independence of the review, in the sense that the review reflects the views of the VECTRA personnel, rather than those of the Operator.

In order to protect confidentiality, neither the Operator nor the projects are referred to by name. That is, within this report, both are made anonymous. This should in no way diminish the value of the review.

2.0 DESCRIPTION OF PROJECTS

2.1 UK-Based Project (A)

The UK-based project (Project A) involved the design of a fixed, normally unattended installation (NUI), to develop two gas fields in the North Sea. One of the fields was to be developed using a subsea production facility, tied back to the fixed installation. The second field was to be produced through the fixed installation, which was to be a minimum facilities well head platform. A brief description now follows.

The platform topsides comprised a four-deck trussed structure, including helideck and wellhead mezzanine deck. The topsides were supported on a steel piled three-legged jacket. The process system consisted of allocation metering, methanol and corrosion inhibitor injection, and primary water separation and disposal. Processed fluids were then combined with the fluids from the subsea development, prior to export via pipeline to a riser tower, bridge-linked to an existing installation.

Topsides equipment therefore included: riser ESDVs, production and test manifolds, production separator, produced water de-gasser, vent KO drum, water treatment package, cold vent boom, diesel engine-driven power generators, diesel and water storage tanks, temporary pig launcher/receiver and crane. An equipment room and overnight emergency accommodation were provided in a single enclosure, which served also as a protected muster point.

The EPIC contract for the platform was awarded to a major engineering contractor, with the platform design work being undertaken in the UK. The FEED (Front-End Engineering Design) phase of Project A ran from July to October 1998, a period of approximately four months. The Design Safety Case for the development was submitted to the HSE in mid-November 1998.

2.2 USA-Based Project (B)

The USA-based project (Project B) involved the design of a fixed, normally manned installation. The plan was to develop two gas fields, approximately 35 miles offshore Trinidad. The platform was designed to be able to accommodate a Minimum Area Self-Erecting Rig (MASE), which would allow SIMOPs to be undertaken. At some future date, a nearby subsea field was planned to be tied into the platform, with compression planned to be installed after 15 years of production. These last two options were not part of the FEED design.

The facility consisted of a single production train with standby units for critical rotating machinery. The production from each of the nine initial wells flowed to a twelve well production manifold for routing to a production separator; a twelve well test manifold was also provided. A three-phase production separator was provided for the removal of free water. The separated gas was metered prior to export. Any condensate separated was metered and re-injected into the metered export gas by pressure differential, induced by a control valve in the gas line.

A produced water treatment package was installed to cater for the predicted water production during late life, including future production from a subsea development.

The recombined gas and condensate flowed to the export pipeline via an Emergency Shutdown (ESD) valve, located on the Cellar Deck to isolate the platform systems from the pipeline. A pig launcher was provided to enable periodic removal of water from the pipeline and to distribute corrosion inhibitor.

Provision was made to inject a range of chemicals into the production system to manage corrosion and prevent or remove hydrates. The systems downstream of the wells were conventional carbon steel and suitable corrosion management systems were provided. Provision was made to monitor corrosion and to inject inhibitors into the production equipment.

A fully serviced permanent accommodation for 24 people was provided to cater for the normal crew of eight and two visitors, and the wireline or coiled tubing well intervention crews. The main 24-person accommodation was designed to be a Temporary Refuge for the maximum complement of 24 during well intervention.

A FEED contract was awarded to a major US contractor in August 1998. This FEED stage of the work ran from August 1998 to March 1999, when work was terminated due to the prevailing economic conditions. At that stage, the FEED was approximately 80% complete. Since then the project has progressed to the detailed design stage, which started up again in March 2000. A FEED Design HSE case was developed, which was submitted internally within the Operating Company.

2.3 Key Differences

In the context of the present study, the following observations are made in relation to the differences between the two projects.

Project A involved the design of an NUI for the UK North Sea, whereas Project B was concerned with a manned platform designed in the US, for installation offshore Trinidad. In addition, the two platforms had different requirements in relation to processing of hydrocarbons. It was inevitable therefore that differences would exist between the two designs, as described in the previous section. However, the similarities are that both were gas platforms, with FEED phases conducted at approximately the same time and over approximately the same timescale. The Operating Company was the same in both cases, so it could be expected that similar corporate standards would be applied to both projects (see Section 4).

All other things being equal, it would perhaps be expected that the simpler design of Project A would have given rise to fewer safety issues and hence a reduced focus on analysis. The extent to which this expectation was borne out by experience is discussed in Sections 5 and 6.

Although designed in the US following a GoM-type approach, the fact that the Project B platform was to be installed outside the GoM removed it to some extent from the influence of US Regulation (see Section 3). Hence, additional information regarding GoM practice is provided, based on VECTRA's experience of other US-based projects, to ensure that the assessment in the context of the ODE report is valid.

3.0 REGULATIONS AND STANDARDS

In terms of regulations governing offshore safety, Project A was subject to the current UK regulations, the majority of which have been introduced since the Cullen Inquiry into the Piper Alpha disaster [2]. These regulations have together created a safety regime based on 'goal-setting' rather than prescription.

Under the umbrella legislation of the Health and Safety at Work etc. Act 1974 [3], the regulations governing all UKCS developments include:

- Offshore Installations (Safety Case) Regulations 1992 [4]
- Offshore Installations and Pipeline Works (Management and Administration) Regulations 1995 [5]
- Offshore Installations (Prevention of Fire and Explosion, and Emergency Response) Regulations (PFEER) 1995 [6]
- Offshore Installations and Wells (Design and Construction, etc) Regulations (DCR) 1996 [7]

As well as these and other regulations, detailed guidance, and in some cases an Approved Code of Practice (ACOP), is provided to support the regulations.

In other discipline areas (e.g. structural, process, piping, electrical), a range of British and international standards (BS/ISO, API, ANSI, IEC, etc.) are generally adopted.

In contrast, in the US/GoM, the approach in relation to safety is governed more by the influence of standards than by regulation. The relevant regulatory body in the US is the Minerals Management Service (MMS). The MMS's role is to oversee the safety and environmental control of Outer Continental Shelf (OCS) operations. The general aim is to ensure that the design and operation of the facilities complies with the relevant API and other standards. It should be noted that the US Coast Guard covers the design and operation of floating production facilities, such as Spars and TLPs. However, there are no regulations equivalent to those in the UK and, in particular, no requirement for a Safety Case to be prepared or submitted. Operators and design contractors instead work to the following standards:

- API RP 14C Recommended Practice for Analysis, Design, Installation and Testing of Basic Surface Safety Systems for Offshore Production Platforms
- API RP 14G Recommended Practice for Fire Prevention and Control on Open Type Offshore Production Platforms
- API RP 14J Recommended Practice for Design and Hazards Analysis for Offshore Production Facilities [8]
- API RP 75 Development of Safety and Environmental Management Program for Outer Continental Shelf (OCS) Operations and Facilities
- API RP 500 Recommended Practice for Classification of Locations for Electrical Installations at Drilling Rigs and Production Facilities on Land and on Marine Fixed and Mobile Platforms
- API RP 521 Guide for Pressure Relieving and Depressurising Systems

All major operators in the GOM apply API 14J [8], which requires the application of Hazard Identification techniques such as HAZOPs. A HAZOP is recognised as a valuable tool in the overall design process. In the deepwater (+1500ft) areas of the GOM, there is a requirement for the operator to produce a Deepwater Operating Plan (DWOP). The DWOP describes the facility and how it will be operated, along with the decision making process which led the operator to the chosen configuration. Part of the DWOP is the requirement to have undertaken a HAZOP and, where required, the DWOP would include risk assessment when competing options have been examined.

Therefore, in terms of safety and hazard management, there are clearly significant differences in approach, which can be summarised as follows:

1. In the UK, duty holders are required to submit a Design Safety Case (DSC), and subsequently an Operational Safety Case (OSC), to the regulatory body, the HSE. This must include an assessment of the risks to personnel and a demonstration that the risks will be reduced to a level that is as low as reasonably practicable (ALARP) [4]. Conversely, in the US, the requirements are based on conformance with standards.
2. Although some of the tools used for hazard management (e.g. HAZOP, FMEA, consequence analysis etc., see [8]) are common, the requirement in UK regulations for quantitative risk assessment [4] generally has led to a greater degree of analysis being performed. In the US, there is no requirement to calculate risks to personnel.
3. Whilst US standards contain some similarities, UK regulations require greater provision of measures to protect personnel in the event of a major accident (e.g. provision of temporary refuge (TR), TR integrity, good prospect of rescue and recovery) [4,6]. These arise partly due to the harsher environment of the UKCS.

As noted in [1], these differences mean that a greater level of safety-related engineering effort is required for UK installations, compared with those in the GoM.

For design projects, the submission of the DSC imposes constraints, particularly for ‘fast-track’ projects. For Project A, the overall project schedule was such that the submission date for the DSC coincided approximately with the end of the FEED stage. Although the design overall proceeded on a similarly fast-track, this meant that many safety-related decisions on the design were compressed into the first four months from contract award.

For Project B, although the platform was to be installed outside the GoM, the contractor followed a typical GoM-type approach. However, the project was subject to some additional influence from the Trinidadian authorities. In particular, the Ministry of Energy required a report to be submitted at the end of the FEED stage, which included a short description of the approach to safety during design.

4.0 OPERATING COMPANY STANDARDS

The approach to safety on both projects was influenced by a commitment to the Operator's corporate health, safety and environment policy, together with the setting of high level goals linked to the policy. In both cases, the project goals included a commitment to reduce personnel risks to a level that is ALARP. In the case of Project A, quantified targets were set both for individual risk and impairment of the TR. For Project B, although not a regulatory requirement, a safety case was to be prepared, in accordance with the corporate standard. Note however that the safety case was not produced at the end of the FEED stage, but was to follow later. Instead, a FEED close-out safety report was produced, based around a safety case approach. Similarly, the calculation of risks for Project B was for internal purposes only.

Another feature of both projects was that the Operator asked the design contractor to use the Operator's own integrated risk assessment package. This was a relatively unusual step in terms of this type of engineering design contract. For the Operator, the aim was to be innovative in using the capabilities of the package as early as possible to influence the design.

To facilitate use of the package by the contractor's personnel, a three-day training course was provided to three representatives of the contractor for Project A. The software was then made available in the contractor's offices, linked to the Operator's headquarters by a fast (ISDN) communications link.

As the Project B contractor was US-based, instead of a training course, individual tutoring was provided by the Operator to contractor personnel. Again, the software was made available in the contractor's offices and a communications link provided back to the UK. It should be noted however that there were some delays and reliability issues associated with this connection, which hindered use of the package at times.

5.0 OVERALL APPROACH TO SAFETY

For both projects, the overall approach to safety followed established hazard management practice, adopting the preferred hierarchy of avoidance/prevention, detection, control, mitigation, evacuation, escape and rescue. In the UK, this strategy has been recognised for some years as best industry practice and is underpinned by regulations, e.g. [6]. Hence, the Project A contractor was familiar and experienced with the approach. However, for Project B, the influence of the Operator's own standards were the prime driver (see Section 4 above). For each project, examples of the measures developed in each category during FEED are given in Table 1 below.

Within the contractor's design team for Project A, the safety discipline was represented by a Lead Engineer, supported by a team of four safety engineers. In general, the interaction with other disciplines was good, with safety input sought and given at all key decision points. Occasionally, there were signs that the safety team was being asked to 'justify' design decisions after they had been taken. This was partly due to the short project timescale, which had an impact overall on decision-making, and partly because the safety team were on a learning curve with respect to the Operator's risk assessment package (see Section 6). Nevertheless, the team was able to exert a positive influence over aspects of the design, for example in relation to blast wall location and strength.

As mentioned in Section 3, the fast-track nature of the project tended to force all decision-making into a relatively short period. It was evident that this imposed significant pressures on a number of key individuals within the design team. From a safety perspective, some issues that might otherwise have been addressed within the DSC were 'held over' to the OSC. (This may have led subsequently to greater cost, if modifications were then found to be necessary, since construction would have commenced). However, whether or not the design was 'less safe' as a result is difficult to say.

For Project B, the contractor's safety team consisted of three engineers. Compared with Project A, this reduced resource reflected the 'standardised' approach adopted typically within the US. However, because the Operator sought to introduce UK practice, involving for example risk-based design decision-making, tensions arose between the Operator's safety representative and the contractor. This led to greater intervention by the Operator in relation to design decisions. The impact of the short project timescale was perhaps less critical here, as the safety case (including full QRA) was not prepared until later in the detailed design phase.

Table 1: Examples of hierarchy of safety measures for both projects

	Project A	**Project B**
Prevention	NUI; number of intervention visits minimised. Open platform with good ventilation. Hydrocarbon risers run within caisson, within jacket.	Removed pipeline spool piece out of dropped object zone. Use of single valve double block and bleed valves to reduce leaks on the system.
Control	Automatic ESD and blowdown of	Separation of closed and open drains

	topsides inventory. Provision of blast wall between TR and riser ESDV area.	systems. Provision of fire and blast wall to separate the process area and utility/accommodation areas. Automatic blowdown of process plant. (Not required by any codes and standards in the USA).
Mitigation	Application of PFP to critical structural elements.	Initiate deluge on high level gas detection. (Not common practice in the GoM).
Escape and Evacuation	Provision of TEMPSC, life rafts, escape to sea ladders, descent devices.	Provision of 200% TEMPSC facility. (Not common practice in the GoM). Provision of multiple escape routes to the accommodation area (exceeding the requirements of API 14J). Escape routes included a protected stair tower to enable personnel to move from the cellar deck to the drill deck, under conditions of jet fire in the process area. (Again, this is not part of the API 14J requirements).

6.0 CONSEQUENCE AND RISK ASSESSMENT

As noted earlier, for both projects, the design contractor was asked to use the Operator’s own integrated risk assessment package for both consequence and risk analysis. This section provides details on the extent of the analysis undertaken on the two projects and the influence of any calculations on the design.

6.1 Risk Assessment Package

As the Operator’s risk assessment package was used in both projects, comparisons can be made of the extent of the risk and consequence assessment carried out in both cases. One of the main features of the risk assessment software is its auditability. This allows assessments to be peer reviewed as easily as possible and revisited at a later date without the need to, say, unravel a complex series of spreadsheets that might be used in other cases. All of the data connected with an assessment is stored in a central database, so that all users of the system access the same data.

These features allow a system administrator to examine the database and determine the number of modelling runs that have been performed, the number of versions of an installation that have been created and other statistics. This makes a quantitative comparison between different projects possible.

The process of performing a risk or consequence assessment in the Operator’s software is a three-stage process. The first stage is to input ‘set-up’ information that gives a physical description of the platform and the hydrocarbons that are on it. An installation is described in a series of platforms, decks, modules and isolatable systems and, for example, a platform may contain many decks and a module many isolatable systems. For both the installations under discussion here, there was only one platform. Different types of information are held at the different levels. Information at the installation level is applicable to the whole installation and includes the windrose and position of the temporary refuge. Information on an isolatable system is applicable only to that isolatable system. Note that, for example, a module cannot be created without first creating the deck, platform and installation that lie above it.

Once an installation has been defined to a level detailed enough to carry out the calculations required, a ‘knowledge base’ is run. A knowledge base is a linked series of models that combine frequency, consequence and risk data. Knowledge bases exist for the major hazards and because the knowledge of how the models link together is contained within the software, the methodology is always consistent between different users of the system. In general, knowledge bases are constructed so that they run a hazard for thousands of different scenarios, such that the risk picture is assembled from thousands of smaller snapshots. Because of the wealth of information that is generated, only a limited range of output data is made available and, to gain detailed information on a specific scenario, a ‘single-run’ knowledge base is used. These ‘single-run’ knowledge bases contain consequence models that run for a single scenario and provide detailed information on that scenario.

When a knowledge base has been used for a particular installation, subsequent changes to the set-up information that has been used in the calculations are prevented. This avoids inconsistencies between output and input data. If such changes are required, say for example to the pressure of an isolatable section, a new version of the installation, without the associated knowledge bases, is generated, with the two versions being identical apart from the pressure of the isolatable section. Further changes to the set-up information can then be made until a knowledge base is run on the new version. In this way, a series of versions of the installation is created, each differing slightly from the last. In general, during a FEED phase, early versions of the installation contain a scarcity of information and often ‘best guesses’ are used to place equipment or determine inventory pressures. As the FEED progresses and the design matures, different versions of the installation can be used to perform ‘what-if’ calculations.

The final stage of an assessment is to report on the results. Because of the wealth of information produced by a knowledge base, it is not realistic to look at all the results for every run. Therefore, a subset of results is generated and viewed by the user. The generation of the reports is also logged in the database and their use is another measure of how the software has been employed.

In the database, installations are identified by a unique numeric code. Normally this code is not available to the user, as a unique name and version number identify the installation. However, in order to maintain the anonymity of the projects, the codes are used here. Note that if, say, version 4 is created from version 3, then the numeric code associated with version 4 is greater than that for version 3.

The following sections give statistics on the use of the Operator’s risk assessment software for the UKCS and USA projects.

6.2 Project A

6.2.1 Versions of Installation

A total of twenty-eight different versions of the installation were created during the FEED phase of Project A. Table 2 shows the number of different components and obstacles that make up the different versions of the installation.

Table 2: Versions of installation for Project A

Installation Code	Number of Systems	Number of Modules	Number of Decks	Number of Platforms	Number of Obstacles
25282	0	2	1	1	2
25283	0	0	0	0	0
25284	0	0	0	0	0
25285	0	0	1	1	65
25287	1	1	1	1	65
25288	2	1	1	1	69
25289	2	1	1	1	72
25290	1	1	1	1	65
25291	5	4	1	1	65
25292	5	4	1	1	71
25293	5	4	1	1	75
25294	5	4	1	1	73
25295	5	4	1	1	71
25296	5	4	1	1	72
25298	7	4	1	1	72
25300	0	0	6	1	0
25301	0	0	1	1	0
25304	7	4	1	1	1989
25305	8	4	1	1	1989
25307	7	4	1	1	1963
25308	7	4	1	1	1989
25309	6	3	1	1	1989
25310	8	3	1	1	1963
25311	7	4	1	1	1939
25312	7	4	1	1	986
25313	7	4	1	1	1111
25314	7	4	1	1	1112
25315	7	4	1	1	1105

Table 2 also shows the number of obstacles for each version of the installation. Each obstacle corresponds to a pipe, beam, wall, vessel, floor or grating, and together they describe the installation. In the early stages of a FEED phase, the details of the obstacles may not be known in detail. In order to generate valid predictions of explosion overpressures and gas or smoke dispersion, the installation must be well represented by the obstacles. For example, if no detailed piping is contained in the description, the overpressure predictions will be low. Thus, the number of obstacles in the description is a measure of the stage of the FEED phase and the accuracy of the modelling. Figures 1 and 2 show this information graphically.

6.2.2 Knowledge Base Runs

At the time of the FEED phase of Project A, there were ten different knowledge bases in the software. These are listed and numbered in Table 3 below.

Table 3: Knowledge Bases

1	Explosions*
2	Fires*
3	Ship impact*
4	Structural failure*
5	Single-run explosions
6	Single-run fires
7	Subsea pipeline failure
8	Other models
9	Risk assessment
10	Fires and smoke*

The knowledge bases marked * can be used to give risk data that is then summed in the 'risk assessment' knowledge base. The 'Other Models' knowledge base contains frequency models for riser failures and blowouts and a missile impact model. Note that a run of a knowledge base may consist of between one and five separate models, depending on the amount of modelling that the user requires.

In addition to the knowledge base runs, in the isolatable system part of the set-up, models can be run to generate the immediate ignition probability following a release and the outflow from a puncture or rupture in pressurised process equipment. These models are classed differently to the knowledge bases models, because they are fundamental models that are used by a large number of the knowledge bases.

When a model is run, it automatically checks that the input data is consistent. If it is not, an error message is generated. Also, if the model is outside its region of applicability, an error message is generated. The number of knowledge bases that result in an error can be detected and these figures are recorded for the different versions of the Project A installation.

Table 4 shows the number of runs, successful runs, successful non set-up runs and the number of successful knowledge base runs. These results are recorded graphically in Figure 3.

able 4: Knowledge base and model runs for Project A

Installation Code	Model Runs			Successful KNB Runs
	Total	Successful	Successful, non set up	
25282	2	0	0	0
25285	10	3	3	3
25287	3	3	1	1
25288	5	3	1	1
25289	1	1	1	1
25290	10	9	9	4
25291	96	87	81	43
25292	3	3	3	3
25293	2	2	2	2
25294	1	1	1	1
25295	1	1	1	1
25296	41	8	4	6
25298	99	95	89	89
25304	31	20	20	10
25305	20	9	7	5
25307	15	14	14	10
25308	4	3	3	1
25310	155	108	94	44
25311	5	3	3	3
25312	2	2	2	2
25313	2	2	2	2
25314	1	1	1	1
25315	61	50	50	38
Total	570	428	392	271

The runs can also be split according to the knowledge base that was run and this information is given in Table 5 (where blank cells are given, this indicates that no runs were carried out) and Figure 4.

Table 5: Successful runs in each knowledge base for each installation version (Project A)

Installation Code	Explosions	Fires	Ship impact	Structural failure	Single-run explosions	Single-run fires	Subsea pipeline	Other models	Risk assessment	Fires and smoke	Total
25282											**0**
25285							3				**3**
25287	1										**1**
25288	1										**1**
25289	1										**1**
25290						4					**4**
25291	3	2			1	37					**43**
25292	3										**3**
25293	2										**2**
25294	1										**1**
25295	1										**1**
25296	3				2		1				**6**
25298						89					**89**
25304	4		1		2	1		1			**9**
25305						2	3				**5**
25307	9	1									**10**
25308		1									**1**
25310	1	9	3	2		9	12	2	4		**42**
25311	3										**3**
25312	2										**2**
25313	2										**2**
25314	1										**1**
25315	38										**38**
Total	**76**	**13**	**4**	**2**	**5**	**142**	**19**	**3**	**4**	**0**	**268**

Table 6: Number of reports for each installation version (Project A)

Code	Total	Explosions	Fires	Ship impact	Structural failure	Single-run explosions	Single-run fires	Subsea pipeline failure	Other models	Fires and smoke
25285	**3**							3		
25287	**2**	2								
25288	**1**	1								
25289	**2**	2								
25290	**9**						9			
25291	**57**	5	4				48			
25292	**7**	7								
25293	**2**	2								
25294	**1**	1								
25295	**1**	1								
25296	**5**	1						4		
25298	**95**						95			
25304	**8**	7				1				
25305	**6**						3	3		
25307	**22**	21	1							
25310	**67**	7	9	5			9	31	3	
25311	**4**	4								
25312	**4**	4								
25313	**3**	3								
25314	**2**	2								
25315	**56**									
Total	**357**	**70**	**14**	**5**	**0**	**1**	**164**	**41**	**3**	**0**

6.2.3 Reporting on Successful Runs

It is only possible to produce output reports on successful runs, since output data does not exist for erroneous runs. The number of reports produced is shown in Table 6 and Figure 5.

Note that report information is automatically generated from the risk assessment knowledge base and so this data does not appear in Table 6. Combined, the presented data shows the level to which the risk assessment software was utilised during the FEED stage of the UK project. The use to which these results were put is discussed briefly in Section 6.4.

6.3 Project B

6.3.1 Versions of Installation

A total of sixteen different versions of the installation were created during the FEED stage. Table 7 shows the number of different components that make up the different versions of the installation.

Table 7: Versions of installation for Project B

Installation Code	Number of Systems	Number of Modules	Number of Decks	Number of Platforms	Number of Obstacles
20151	5	7	2	1	519
20158	8	7	2	1	519
20174	8	6	2	1	519
20178	8	6	2	1	519
20190	9	7	3	1	425
20191	9	7	3	1	425
20192	9	7	3	1	1155
20194	9	7	3	1	1748
20201	13	8	4	1	1748
20204	9	8	3	1	736
20210	9	7	3	1	1725
20211	9	7	3	1	739
20214	11	8	3	1	736
20218	9	7	3	1	739
20223	11	8	3	1	736
20224	11	8	3	1	736

Table 7 also shows the number of obstacles in each version of the installation. Figures 6 and 7 show this information graphically.

6.3.2 Knowledge Base Runs

At the time of the FEED phase of Project B, there were ten different knowledge bases with the software, the same as for the UK project, described in Section 6.2.2.

Table 8 shows the number of runs, successful runs, successful non set-up runs and the number of successful knowledge base runs. Since a knowledge base contains up to five model runs, the number of model runs is always equal to, or greater than the number of knowledge base runs. These results are recorded graphically in Figure 8.

Table 8: Knowledge base and model runs for Project B

Installation Code	Model Runs			Successful KNB
	Total	Successful	Successful, non set-up	
20151	150	134	85	70
20158	38	32	24	11
20174	22	20	16	8
20178	249	159	157	99
20190	8	4	0	1
20191	20	4	4	4
20192	13	6	4	3
20194	46	41	13	3
20201	27	18	10	8
20211	20	14	14	4
20214	24	20	12	4
20218	4	3	3	1
20224	55	41	25	9
Total	**676**	**496**	**367**	**225**

The runs can also be split according to the knowledge base that was run and these figures are given in Table 9, where again blank cells indicate no runs, and Figure 9.

Table 9: Successful runs in each knowledge base for each installation version (Project B)

Installation Code	Explosions	Fires	Ship impact	Structural failure	Single-run explosions	Single-run fires	Subsea pipeline failure	Other models	Risk assessment	Fires and smoke	Total
20151	19	15	5		1	1	1	4	22	2	**70**
20158		7							4		**11**
20174	1	2	1	1					3		**8**
20178	18	23	2	2	1	4	17		22	1	**90**
20190	1										**1**
20191	3	1									**4**
20192	3										**3**
20194	3										**3**
20201	1						6	1			**8**
20211	2	2									**4**
20214	4										**4**
20218	1										**1**
20224	4					5					**9**
Total	**60**	**50**	**8**	**3**	**2**	**10**	**24**	**5**	**51**	**3**	**216**

Table 10: Number of reports for each installation version (Project B)

Code	Total	Explosions	Fires	Ship impact	Structural failure	Single-run explosions	Single-run fires	Subsea pipeline failure	Other models	Fires and smoke
20151	**59**	24	22	1		1		5	4	2
20158	**11**		11							
20174	**4**	2	2							
20178	**142**	24	56	3	1	1	5	40		1
20190	**2**	2								
20191	**4**	4								
20192	**8**	8								
20194	**28**	24	4							
20201	**24**	14						8	2	
20211	**42**	20	22							
20214	**24**	24								
20218	**4**	4								
20224	**23**						22			1
Total	**375**	**150**	**117**	**4**	**1**	**2**	**27**	**53**	**6**	**4**

6.3.3 Reporting on Successful Runs

It is only possible to produce output reports on successful runs, since output data does not exist for erroneous runs. The number of reports produced is shown in Table 10 and Figure 10.

Combined, the presented data shows the level to which the risk assessment software was utilised during the FEED stage of the USA project. The use to which these results were put is discussed briefly in Section 6.4 below.

6.4 Comments

For Project A, the contractor's safety team was familiar with, and had experience of, the principles of risk and consequence assessment, but had not used the Operator's risk assessment package before. The personnel concerned understood the benefits that could be gained from consequence assessment software that is based on extensive experimental testing. However, the difference between the methodologies forced upon them by the software and their own in-house techniques created some issues.

Probably foremost amongst these issues was that the team did not realise how using the risk assessment software would make the assessment less time-consuming. For example, because all data is automatically, centrally stored and cannot be deleted, there is no need to keep detailed records of every input to the system, as they can be retrieved at any time.

As the design philosophy in the USA is largely prescriptive, with little requirement for risk assessment to justify design decisions, such as the removal or addition of safety measures, there was little experience of any similar software in the US contractor's safety team. Therefore, putting together the initial set-up data and running the models was a slower process than anticipated. Also, because the team was unaware of the benefits that could be gained by appropriate use of the software, the necessary information needed to use the software was not made available as quickly as needed, making the use of the software less effective.

That said, the statistics presented in Sections 6.2 and 6.3 indicate a broadly similar level of use on the two projects during the FEED phase, although with differences in emphasis. Given the simpler nature of the UK NUI, this may indicate a greater relative use on Project A.

In both cases, the analyses were used effectively to influence the design, particularly in relation to:

- Layout, to minimise explosion overpressure
- Decisions associated with blast wall location and strength
- Size and duration of jet fires
- Provision of passive fire protection (PFP)

- (Project B) Comparison of the risks associated with reducing the number of decks from two to one. (It was decided to move forward with two decks, due to congestion on a single deck facility).

7.0 OBSERVATIONS RELATING TO THE ODE REPORT

As described in Section 1.1, in relation to safety, the ODE report concluded that there were three key differences between UK and GoM practice:

- Standardisation
- Simplification
- Degree of analysis

In general, VECTRA's own past experience of US projects would tend to support the ODE conclusions. The differences arise primarily because of the different regulatory regimes described in Section 3. Our experience with major operators in the US has been that quantitative risk assessment may be used to distinguish options, but is not usually performed to the extent of calculation of individual risk or PLL.

However, for the specific projects considered in this report, the above differences were not observed. For Project B, the influence of the Operator's UK-type culture on the project meant that the outcome of the design process was not a 'standard' GoM design. It is interesting to note that, during the tender process for Project B, two previous GoM designs were proposed to the Operator by US contractors, and there is a significant difference between these and the present design. The actual design can probably more accurately be described as a 'Mid Atlantic' design. That is, it has some GoM influence, as well as many safety features that were driven by the requirement to comply with in-house standards.

In both cases, simplification was a project objective, due to two factors:

- The nature of the process requirements, i.e. simple gas dehydration and export. (It is likely that a different situation would have arisen if the installations had been oil production platforms).
- The recognition that simplification helps to reduce the risks associated with platform operation.

As the statistics given in Section 6 illustrate, when compared with Project A, the degree of analysis was not considerably reduced on the US-based Project B design, primarily due to the Operator's in-house requirements.

8.0 CONCLUDING REMARKS

Based on the fundamental differences in the safety regimes (Section 3), it was expected that significant differences in the amount of safety-related effort would be observed, with Project A demanding more resources. In practice, it was found that these differences were offset to a large extent by the influence of the Operating Company's corporate standards, which tended to be aligned with the UK safety regime. Therefore, the cost differentials identified in the ODE report were not particularly evident in the two projects discussed here.

Given that the oil and gas business is dominated by large multinationals, all of which have similar corporate standards that apply worldwide, then it could be argued that a similar picture would emerge from other project comparisons (although it may be less evident in US-based operators). In the UK, it is likely that the need for submission of the safety case to the HSE imposes an additional burden in comparison to an internal in-company process. However, this may be a relatively marginal difference, given that a safety case/risk assessment regime is in place.

Note however that this conclusion only relates to safety-related effort (or, more precisely, health, safety and environment-related). It may well be that the other sources of differences in cost identified in the ODE report do indeed exist between the UKCS and the GoM. These sources were not investigated in the present study.

We presume that the Operating Company involved here has adopted a UK-type approach to health, safety and environment partly because it is a UK-based plc, and partly because the regime is seen to reflect best industry practice. In a similar way, there is evidence that elements of the safety case approach are being adopted by other countries in which oil and gas exploration and production is taking place. With a combination of these two factors, it is suggested that any differences that currently exist will in time diminish, as worldwide standards tend to converge.

That said, it is the case that regulations elsewhere are not considered to be as stringent as those in the UK and, at the present time, major oil and gas expenditure is currently focused outside the UKCS. Major investments are being made in areas such as the GoM, West Africa and the Caspian Sea, presumably partly because of lower costs/better returns. Hence, there is perhaps a case for examining options for assisting operators, without in any way relaxing the regulations and standards that exist.

The authors of the ODE report themselves stated:

"It is highly undesirable that the UK's approach to safety should turn away from risk assessment and demonstrating ALARP. It is neither thought necessary nor beneficial."

They then went on to say:

"The real issue here is almost certainly that of establishing a simplified approach to risk assessment by operators and their contractors."

We therefore support the recommendation in the ODE report that a joint DTI/HSE/DETR forum be established to help coordinate and clarify environmental, safety and marine issues.

Nevertheless, the climate of continuous improvement in the UK in relation to safety implies that standardisation in general should be avoided and that operators and contractors should look to make improvements, even if a design were to be repeated.

Against that background, HSE should continue to advise operators on the quality of assessments. The regulations [4] demand "suitable and sufficient quantitative risk assessment". Hence, if HSE believes that the overall approach to risk assessment and the ALARP demonstration has been over-complicated in safety cases, it should be prepared to give operators that feedback, together with guidance on where improvements could be made in future submissions.

9.0 ACKNOWLEDGEMENT

Amey VECTRA would like to thank the Operating Company involved in the two projects for providing the statistics given in Section 6, relating to use of the Operator's risk assessment package.

10.0 REFERENCES

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8. Recommended Practice for Design and Hazards Analysis for Offshore Production Facilities, API RP 14J, American Petroleum Institute, 1993.

Figure 1: Number of platforms, decks, modules and systems on Project A

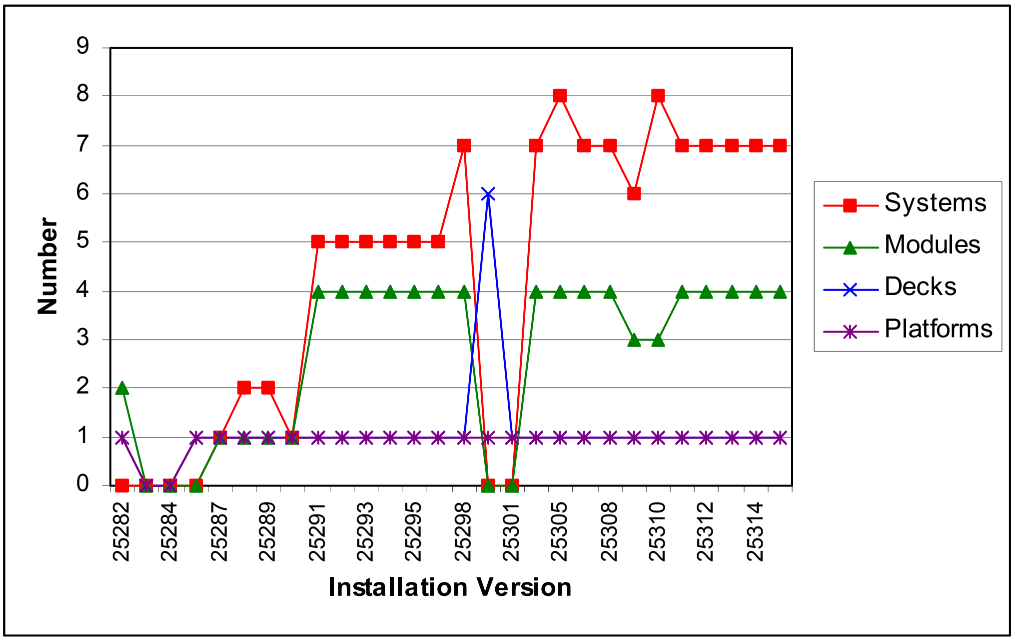


Figure 2: Number of obstacles in different versions of installation for Project A

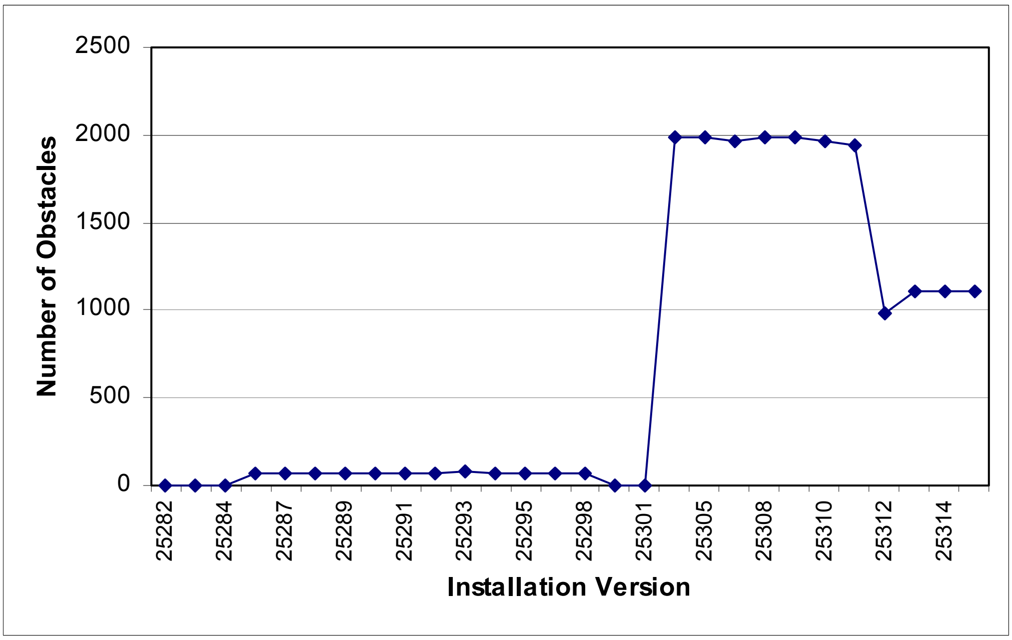


Figure 3: Number of runs and knowledge bases for Project A

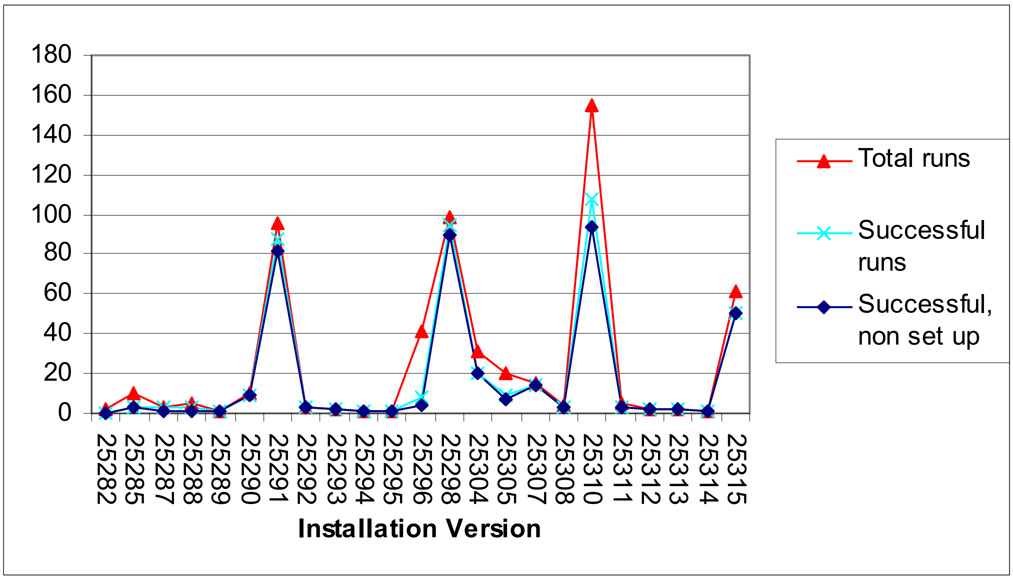


Figure 4: Number of successful runs in each knowledge base for each installation version (Project A)

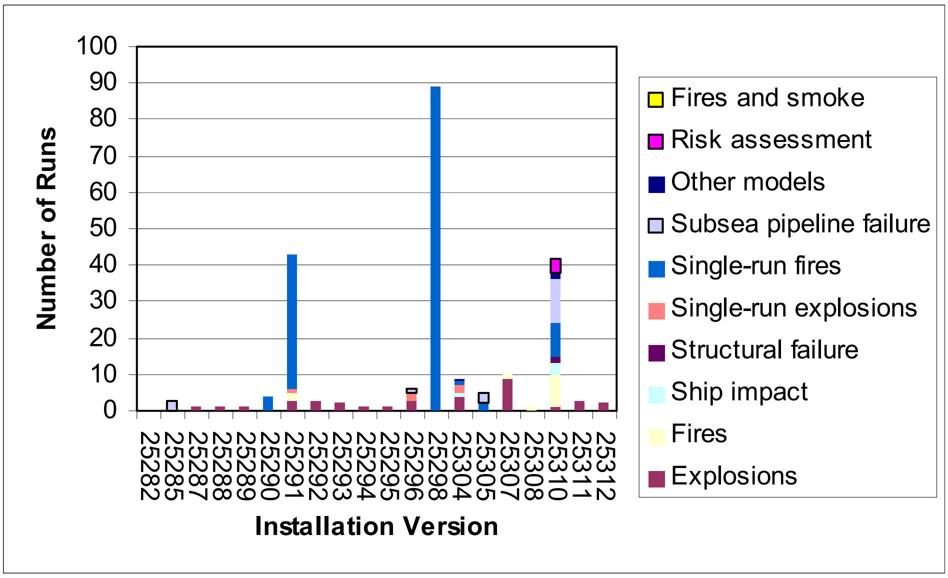


Figure 5: Number of reports generated in each installation version for each knowledge base (Project A)

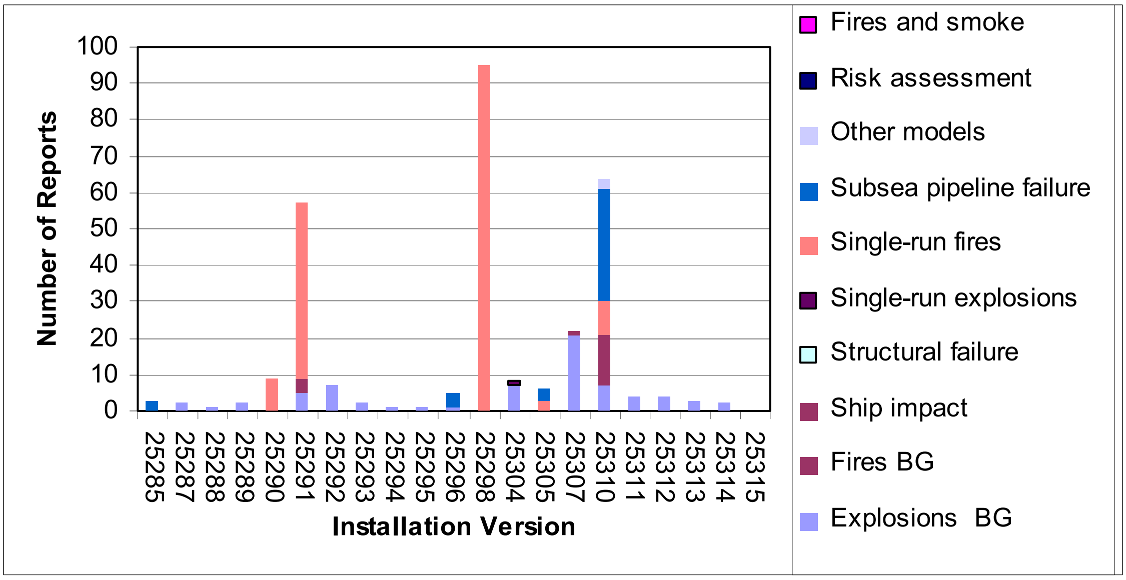


Figure 6: Number of platforms, decks, modules and systems on Project B

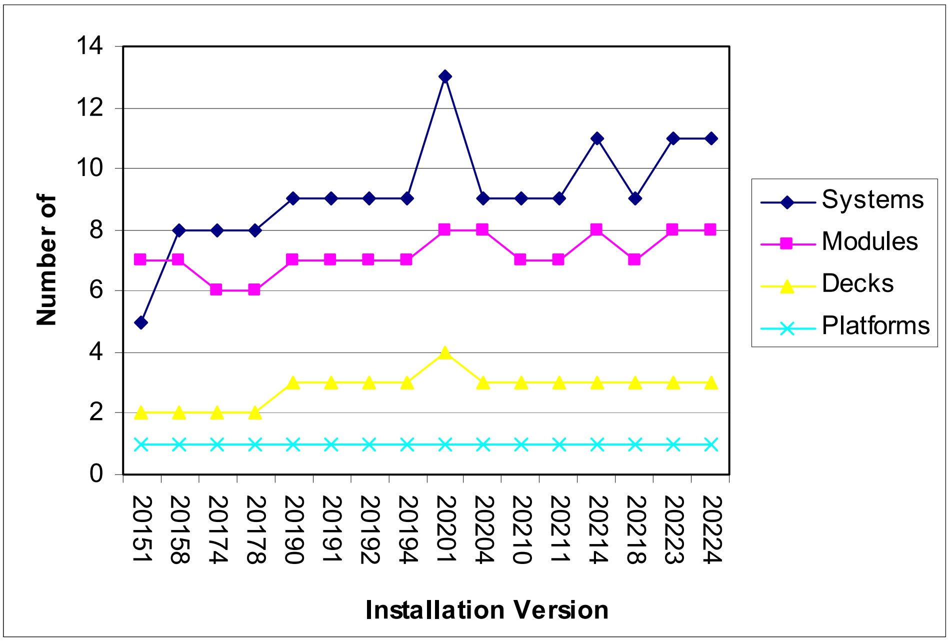


Figure 7: Number of obstacles in different versions of installation for Project B

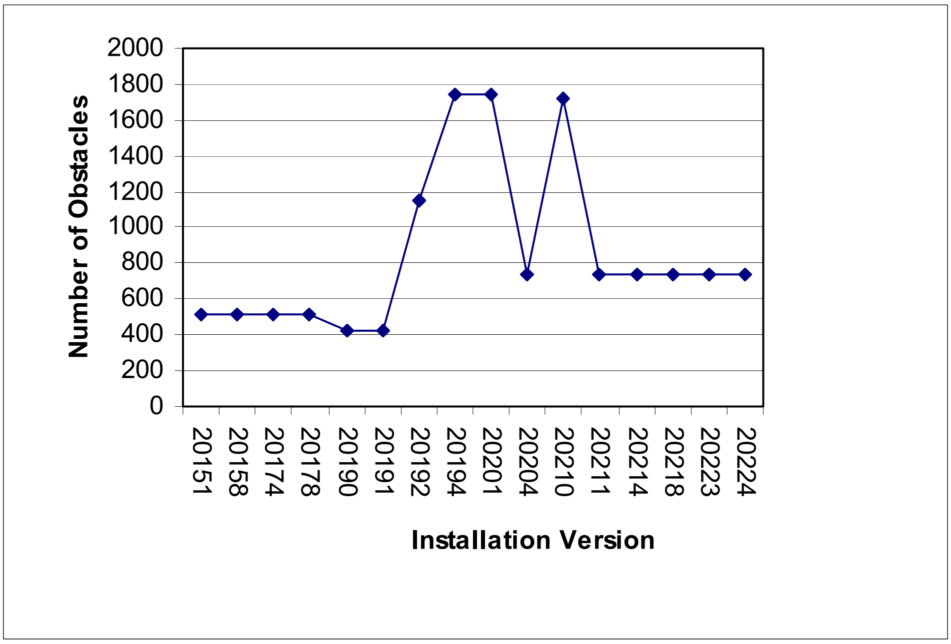


Figure 8: Number of runs and knowledge bases for Project B

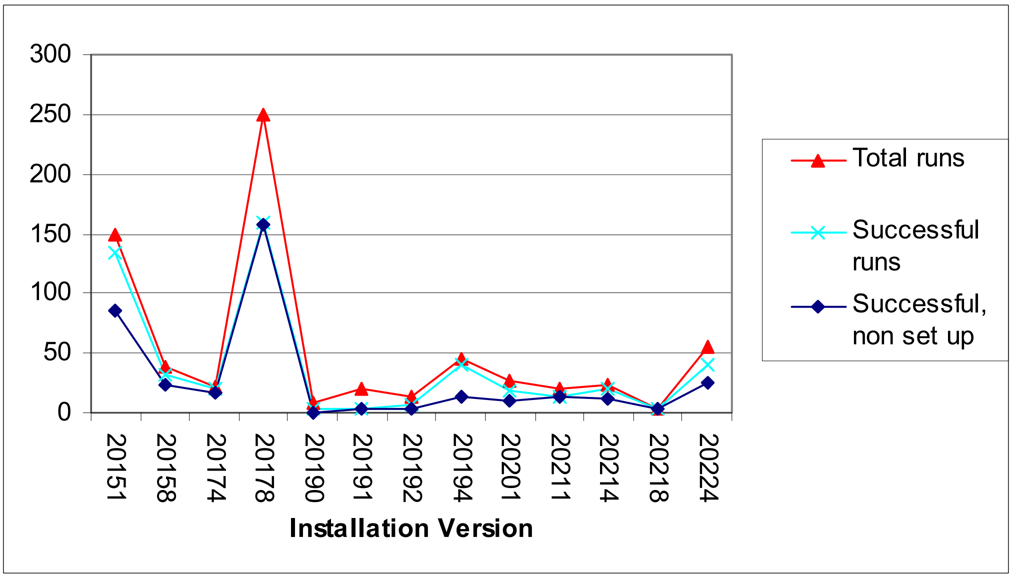


Figure 9: Number of successful runs in each knowledge base for each installation version (Project B)

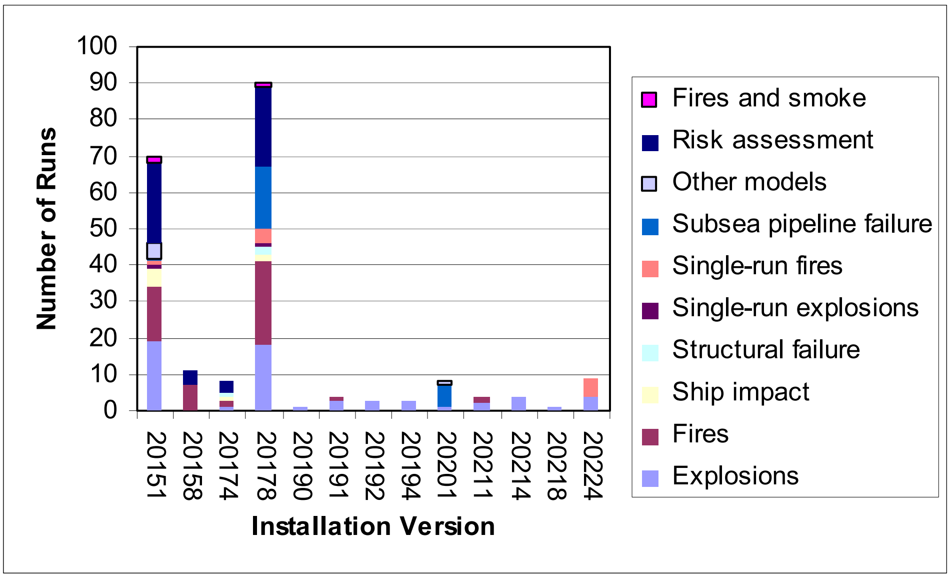
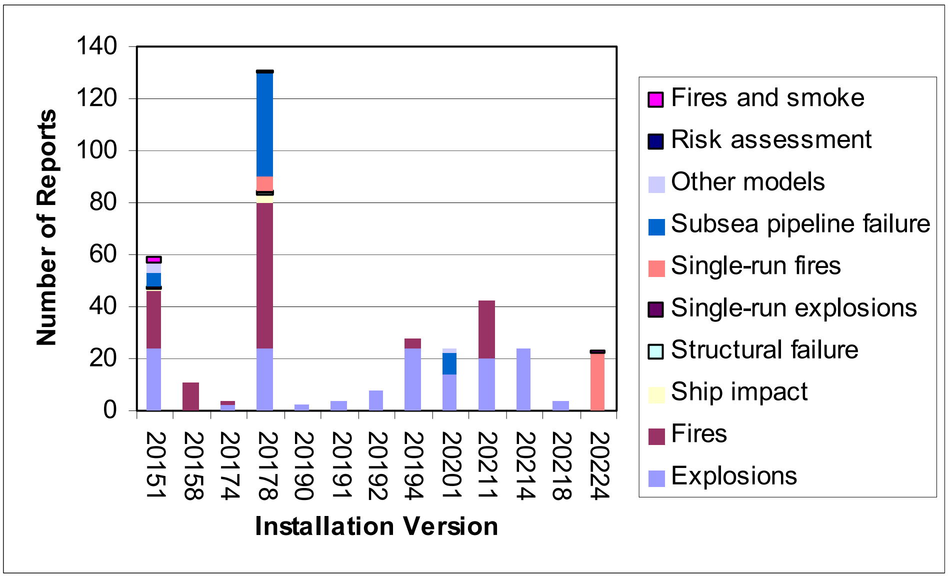


Figure 10: Number of reports generated in each installation version for each knowledge base (Project B)



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