Optimal asset maintenance strategies

Maximizing business value in the modification of LNG carriers into FSRUs

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ASSET MANAGEMENT | RELIABILITY ENGINEERING

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NRS Consulting BV
Delft, The Netherlands
www.nrs-consulting.com

Author contact:
Simon van Benten, MSc.
simon@nrs-consulting.com
+31 6 82 79 74 73

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Management summary

FSRUs are becoming pivotal in addressing Europe's gas shortages and the secure and reliable delivery of energy. In this paper we will explore optimization of maintenance strategies for a major energy project in Southeast Europe - the conversion of an LNG carrier into a Floating Storage and Regasification Unit (FSRU).

Project results at a glance

In this project we have successfully achieved the following for our client:

- Practical implementation of international standards for risk assessment projects to FSRU asset management
- Used existing data & experience to gain actionable insights
- Identified significant potential for increase in uptime by optimizing maintenance strategies

By performing a risk analysis of the conversion project and subsequent analysis of the maintenance strategies valuable results have been uncovered, including:

- Equipment failure modes that have not been covered in current maintenance schemes - which may pose a risk for health and safety compliance
- Added revenue (0,5% to 0,7% annually) by adopting an optimized maintenance strategy for key equipment
- A complete risk review of the whole vessel as an FSRU - creating a blueprint for future FSRU projects.

An evolving industry in times of crisis

Picture an FSRU as a floating gas production plant, repurposed from an LNG carrier. This transformation involves adding a regasification module to the vessel to convert LNG from liquid to gas, making it transferable to onshore gas infrastructure. FSRUs offer flexibility and increased functionality, making them a crucial asset in the evolving LNG market.

As of 2023, around 49 FSRUs operate globally, addressing regasification capacity shortages. Their number has been steadily increasing over the past years. Our focus extends to Northwest and Southeast Europe, the Asia-Pacific, and the US, where FSRU adoption is on the rise. The unique operational shift from a mobile vessel to a stationary plant introduces challenges in ensuring production output and maintenance logistics.

Challenges

Some of the major challenges that the conversion project brings with it are:

- A difference in safety and survey requirements, since the vessel will now become a stationary production facility
- Shifting the focus from reliability to availability - meaning that overall production output becomes the dominant business driver
- Managing an increasing workload for the vessel crew

Production uptime will - next to personal safety - become the dominant business performance driver

In this project we will be focusing on the latter two, while at the same time opening up the way to deal with the first challenge in more effective ways.

Assessing risk and identifying business value

Our project aims to answer two critical questions:

1. How does the change in the function of the vessel alter its risk profile?
2. What maintenance strategies need adjustment for the new operational requirements and risk profile?

We can use a targeted and focused approach to answer these questions by dividing them into five steps. These steps are:

1. Setting up a **risk framework**
2. Create **a list of systems** to analyze
3. Do a risk assessment in multidisciplinary **workshops**
4. **Analyze failure behavior** for the relevant equipment
5. **Optimize maintenance strategies** where this creates benefits for the business

Each of these elements forms an important step in the overall project success.

Setting up a risk framework

Setting up a risk assessment framework requires two elements - a systematic process and assessment criteria. Many international standards exist to help you with the former, both from the maritime world or otherwise.

A risk framework consists of two elements - a systematic process and assessment criteria

The standards will give you a good idea of **wha**t you need to do but they will not tell you **how** you need to do it. Spend some time on understanding each of the steps and making sure each member of the team has the same idea about what needs to be done.

In addition the risk assessment requires an assessment method - an approved corporate ‘measuring stick’ with which to determine the events that fall into each category of low, medium or high risk. In the next chapter we will dive deeper into this topic.

Create a list of systems to analyze

Unsurprisingly, an LNG carrier consists of many pieces of equipment. Not all of them may need to be analyzed, as not all of them will be relevant to the mission success or safe operation of the FRSU. To come to a list of relevant systems we used a two tier approach that is common in risk assessment of large technical projects.

The first step is to create a list of relevant systems for the analysis - systems that are likely impacted by the conversion of the carrier as the FSRU goes into its operational phase based on a high-level, top-down analysis by a team of experts.

The second step is to use this shortened list for the detailed risk analysis using the structured process, set up from an international standard.

Risk assessment workshops

Once we have our list of systems to be analyzed we are ready to move to the phase of the actual risk analysis. In this project we have done a total of 10 workshop sessions of 3 hours each in which a multidisciplinary team assessed the risk of failure of equipment on each of the risk assessment criteria. In total the team analyzed around 2100 pieces of equipment in this way.

Analyzing failure behavior

For each equipment belonging to the medium or high risk categories of the risk assessment an in-depth analysis was made on the failure behavior of the system. In this step we answered the following questions:

- What are the known failure mechanisms that have occurred in the past in the company on similar equipment?
- What are the dominant failure modes - from literature and engineering handbooks - that will most likely occur on the equipment at any point in its lifetime?
- Which of these failure modes are already being mitigated by the current maintenance program and which require more attention?
- Which failure modes can be mitigated by an optimized maintenance strategy in comparison to the current one?

Optimize maintenance strategies

For the optimized maintenance strategies that were identified in the previous step one questions remains:

What are the quantitative benefits - in terms of system uptime and additional revenue - of the optimized strategies?

To answer this question a simple Monte Carlo simulation tool was used, that models each failure mode based on the Weibull parameters, the cost parameters of the different maintenance strategies and project timeline.

Each of the following sections will take you through each steps of the project in more detail and provide tips & tricks to implement them in your own context.

Building Blocks of a Risk Analysis

Our risk analysis framework incorporated the **NORSOK Z-008** standard to use structured process to perform the analysis. While using a structured process in itself does not guarantee a successful - or even useful - outcome, we would recommend using one.

This gets all stakeholders involved in the same mindset and makes it much easier to explain the goals and structure of the analysis to new team members. It also increases transparency if somebody ever wants to audit the process

It is good practice to make the steps in the process very specific: if the analysis will be recorded in an Excel sheet, create a template sheet and ensure the meaning of each column is clear to everyone. Where is what piece of information stored? How does each column relate to subsequent steps in the process?

The risk assessment process requires a few inputs:

- The **organizational strategic plan** - this provides the boundary conditions for the different categories and acceptable levels of risk by answering the questions:
  - What is it that our company has set out to achieve?
  - Which negative events could prevent us from achieving those goals?
- Equipment **demarcation** - a list of systems to analyze.
- Defined **'rules of engagement'** - guidelines to use in the assessment to ensure the team members have the same mental image for important aspects of the analysis, such as how to interpret the presence of redundancy and which assumptions to take in terms of the present of spare parts and capable technical staff in case of equipment failure
- A **consequence assessment method** - the 'yard stick' with which to measure the impact and probability of events, determining the risk level.

The organizational strategic plan forms the basis for the consequence assessment method. In this project we chose a risk matrix approach in which we ranked probabilities and consequences in a risk matrix.

The consequence categories we looked at were **safety, production uptime** and **environmental impact,** as these are the most vital aspects of sustainable business operations for our client.

Managing the overwhelming number of equipment involved in an FSRU required a multi-step risk assessment process. We categorized equipment based on risk and business values, facilitating prioritization for subsequent project phases. The risk analysis identified high, medium,

and low-risk equipment, guiding our maintenance analysis.

The actual analysis was done in multi-disciplinary workshops. During the analysis a group of operational, maintenance and design experts analyzed the selected equipment according to the method described above.

In total 2200 different vessel equipment have been analyzed. Of all those equipment, about 6% - which is a representative figure for such projects, resulting in a total figure of 127 equipment types for the FSRU - went through to the next round for an in-depth analysis on failure behavior and maintenance strategies.

Practical ways to analyze failure behavior

With 127 pieces of equipment selected for in-depth analysis, we performed a Failure Modes and Effects Analysis (FMEA) and evaluated existing maintenance plans.

Next, in a simulation exercise we compared time-based and condition-based maintenance, revealing opportunities for the reduction in the cost of planned maintenance and an increase in production uptime.

Every maintenance analysis exercise follows four basic steps:

- Data collection
- Data analysis
- Exploration of insights

- Decision-making

Our approach involved cross-referencing failure modes, analyzing OEM requirements, and determining equipment eligibility for condition-based maintenance. To avoid an overly detailed exercise we did not complete a full-blown FMEA. Instead, we focused on identifying the most important failure modes only - the ones that would:

- Drive the decision to perform a maintenance action and
- Had not yet been covered by the existing maintenance program

Using Simulation models in maintenance strategy assessment

Utilizing a Monte Carlo simulation model, we optimized maintenance strategies, achieving tangible business results. Out of 127 equipment, 34 were identified for condition-based maintenance, potentially adding $3 million in revenue every year compared to the reference scenario. Alternative, merely optimizing preventive maintenance intervals could already yield an extra $2 million in yearly revenue[1].

[1] Estimates based on average market prices in December 2023

Tips & tricks

To summarize, here are some tips and tricks you can start using today to get the most out of your failure analysis work in your organization:

- Decide whether a failure analysis means that a full FMEA is necessary. Usually this will not be the case - the bottom-up approach tends to be very time-consuming and teams are struggling to show results. Instead a more top-down approach could yield results early in the process - start from what you know are the driving failure modes. Involve the design engineering and OEMs in the process if your organization lacks sufficient knowledge or experience.
- Focus first on comparing strategies instead of detailed tasks, answering the question: “Does it make sense, from a business perspective, to choose one particular strategy over another?”
- A Monte Carlo simulation can be implemented in Excel and provide insight right away. Start simple and take advantage of modern tools, like generative A.I., to get you started.

Conclusions - start with what you already have

In conclusion, the conversion from an LNG carrier to regasification unit provides a natural opportunity to assess risks and opportunities with respect to maintenance and operation of the vessel. There are a few keys to achieving success in projects like this:

- Bringing international standards to the context of the business
- Using in-house data & experience, however imperfect those may be
- Start simple
- Keep moving forward despite uncertainties you may encounter - for instance in completeness of your asset data

We've not only navigated the complexities of FSRU reliability engineering but also provided a blueprint for future projects. By:

1. Setting up a **risk framework**
2. Creating **a list of systems** to analyze
3. Doing a risk assessment in multidisciplinary **workshops**
4. **Analyzing failure behavior** for the relevant equipment
5. **Optimizing maintenance strategies** where this creates benefits for the business

And progressively adding more detail to the analysis where this is appropriate for the context we developed a ‘lean and mean’ approach to uncover value in complex business environments.

Start with what you have and progressively improve from there. Thank you for reading and please reach out if you have any questions!

About NRS Consulting

Founded in 2019 by Simon van Benten - an aerospace engineering MSc graduate with 14 years in asset performance and reliability management - NRS Consulting specializes in the power generation, logistics, and energy distribution industries.

Our focus is to help maintenance and reliability teams use their own data to make better decisions on what maintenance works to do on their equipment - and when to do it. Our ultimate goal is to make sure no machine is ever opened up again to check **why** it is still working.

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