Automating Maintenance

The Rotterdam Petrochemical Cluster

AmCham THE NETHERLANDS

Deltalinqs

RSM Erasmus

Instructions

The Various Levels of This Slide Deck

Level 0	Level 0 covers a concise summary of all of the content.
Level 1	Level 1 contains the essential points and is a brief viewing experience.
Level 2	Level 2 includes further explanations of the information covered in Level 1.
Level 3	Level 3 provides more in depth detail helpful for additional understanding, interesting information, relevant interview quotes and audio snippets.
Level 4	The reference list includes links to external documents, which includes interview transcripts and a video recording.
Back	This arrow returns you to the primary path (Level 1).

Instructions

Using The Navigation Bar

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These arrows allow you to progress linearly through the **primary** path. Using your keyboard's arrow keys will take you through all the available content.

More Details / **Less Details**

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Level 2

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The Project

This project was commissioned by AmCham Rotterdam Chapter and Deltalinqs in collaboration with Rotterdam School of Management as part of a consultancy module. Its aim was to investigate the use of automation in the Port of Rotterdam.

The project focuses on the maintenance processes carried out by petrochemical plants within the Port of Rotterdam.

1. Primarily, the project investigates the current state of automation in maintenance and explores the possibility and benefits of further automation in maintenance.
2. Secondarily, it examines the implications of increased automation on the workforce and the impact of legislation on automation practices.

It combines a literature review of the relevant topics with the insights acquired from eight interviews with a variety of stakeholders including asset owners, contractors, suppliers and consultants. It also incorporates findings from a knowledge roundtable, in which seven stakeholders discussed a variety of topics related to maintenance.

Executive Summary

The Present

Most of the petrochemical plants employ reactive and preventive maintenance strategies for the majority of their equipment. These strategies are time driven and make little use of automated techniques.

The use of a predictive strategy, which uses automation and digitalisation to gauge the health status of a device, is limited to equipment which are central to operations.

The Opportunities

The benefits and opportunities provided by increased automation of maintenance activities fall into three categories:
1) Increased safety for personnel, equipment and plants
2) Improvements in efficiency and reductions in costs
3) The ability to reduce/alleviate the impact of retirements and labor shortages by capturing the knowledge of key personnel.

Executive Summary

The Challenges

Despite the benefits that come with automation, many asset owners lag behind in automating their maintenance processes. There are many reasons for this, both internal and external. We've identified the following barriers to increased automation:

1) A conservative mindset, 2) A lack of knowledge 3) An unsupportive department focus , 4) A lack of time and resources 5) A lack of a strong business case 6) A lack of proof and 7) A lack of options for aging equipment/plants.

Recommendations

Based on the challenges listed above, our interviews with experts and our knowledge roundtable, we've devised three core recommendations which we believe companies should follow.

1. Identify the data that's already available and start with that. Avoid a backwards approach.
2. Start small, think big. Make use of pilot projects, as part of a strategy, to prove the concept and add to the business case.
3. Implement a top down change management process.

Executive Summary

Labor Perspective

Automation presents potential solutions to mitigate the consequences of:
1) A greying workforce
2) Difficulties in attracting technical personnel
3) Difficulties in retaining technical personnel.

However, some soft-side hurdles within the workforce need to be overcome before the petrochemical industry can benefit from the opportunities offered by automation.

Legal Perspective

Legislation/Regulation encourages and discourages companies to increase their level of automation.

It discourages automation by mandating periodic inspections and the use of preventative maintenance.

However, when it relates to safety, the labor inspectorate encourages automation as they believe it is safer and more reliable than people, who make mistakes.

An Important Note

Regarding Our Definition of Automation

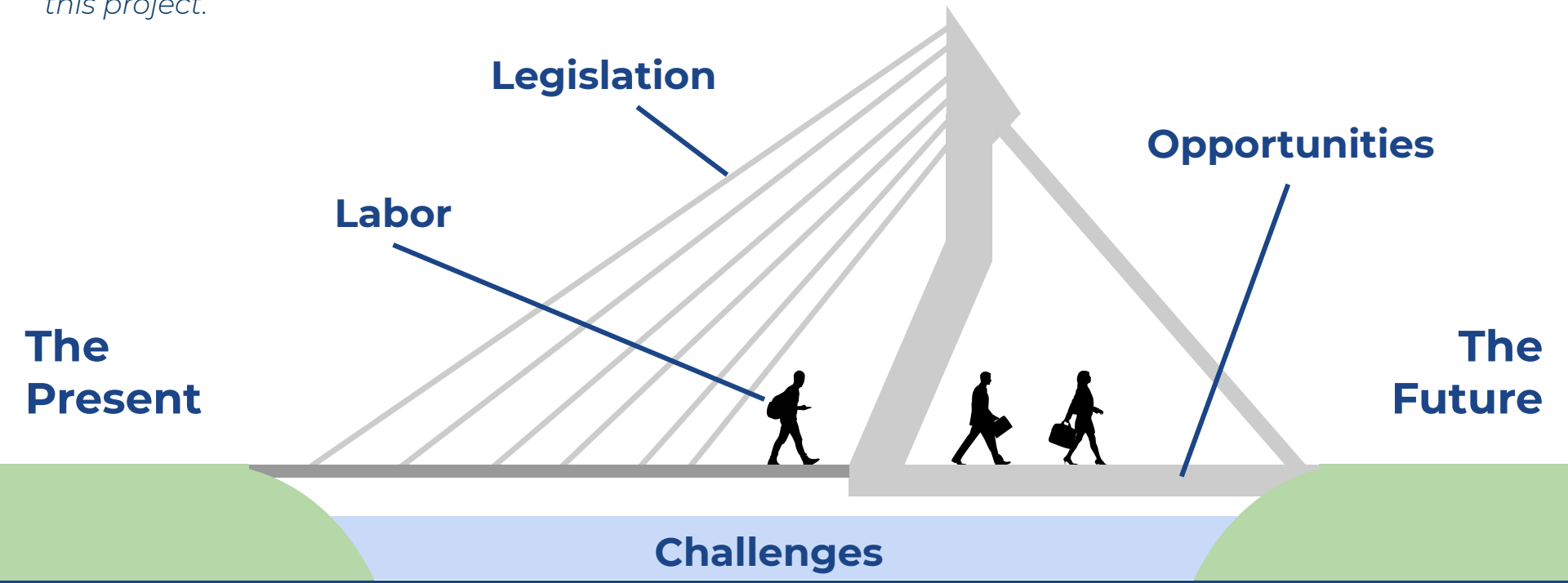
We define automated maintenance as either predictive or prescriptive maintenance.

Automation is used as an umbrella term to encompass concepts such as digitalization, robotization, and Industry 4.0.

The Framework

The Erasmus Bridge as a Metaphor

The foundations and structure of the Erasmus Bridge are metaphors for the topics that were explored in this project.



Petrochemical Maintenance in the Present

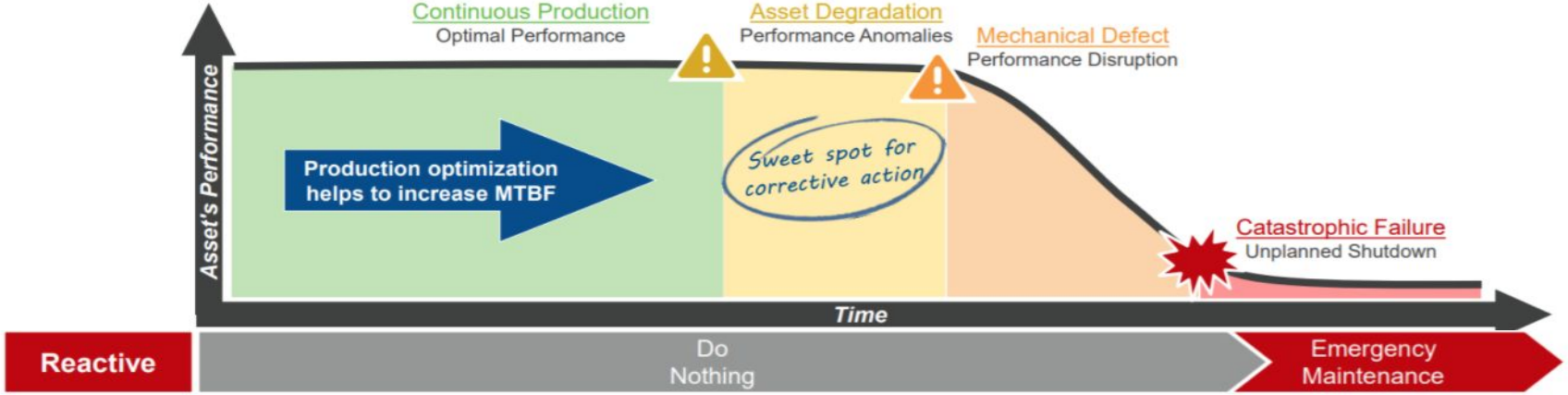
To reach the improved state of automation in maintenance processes in the future, we need the bridge its left part of the foundation to understand the present state.

The Present

The Future

Identifying the Maintenance Strategies 20

Level 1



Reactive maintenance - there is no maintenance planned or scheduled until equipment fails.

Preventive maintenance - involves scheduled maintenance, based on for example, the amount of hours the asset has run, which is determined by the manufacturer or the government.

Predictive maintenance - makes use of sensors to monitor the health of assets. Maintenance is then done based on this status.

Prescriptive maintenance - uses machine learning and artificial intelligence techniques to allow the machine to make its own decision related to how it maintains itself.

Overview of the Maintenance strategies

Level 2

Reactive Maintenance

- Requires someone to **notice failure** and to forward information to the maintenance department.[21]
- Scheduling, outsourcing, supervising and inventory management is all set into action afterwards.[13]
- No use of automation
- Generally, this strategy is used **for non-critical** rotating or static assets (pumps, compressors, pipes, etc.) [13]

Preventive Maintenance

- Assets are **maintained at scheduled intervals**, based on, for example, the amount of hours the asset has run, which is determined by the manufacturer or the government.[20]
- The problem with this kind of maintenance is that it either **comes too early or too late**.[20]
- The intervals for critical assets are often **determined by legislation**.[20]
- **Little use of automation.** For example, a SAP system generates standard plans for maintenance at predetermined intervals.[21]

Overview of the Maintenance strategies

Level 2

Predictive Maintenance

- Condition based strategy reliant on **Internet of Things (IoT)** devices that work in real time to provide continuous updates of the health condition and malfunctions of an asset.[20]
- Uses **sensors and other monitoring gadgets** to gauge when assets require maintenance.[20]
- Data science and the maintenance chain, a **technical** and **human factor** respectively, are combined. [18]

Prescriptive Maintenance

- Uses **machine learning and AI techniques** to allow the machine to make its own decision as to when and how to take maintenance steps. The machines and devices will collect data as it runs and will provide **multiple recommendations.**[20]
- These recommendations are only possible if the **root cause** of the issue can be identified.[20]
- Identifying root causes saves a company time and resources when it comes to opening up assets and identifying failures come from.

Benefits of Current Practices

The Advantages of Reactive and Preventive Maintenance

Reactive

- Maintenance can be done quickly as the strategy involves stockpiles of components.
- No investment in automated technologies required.

Preventive

- Future maintenance work is preplanned and standardized, resulting in more uptime.
- Results in minimum mean time to repair (MMTR) and maximum first time right (FTR) reducing operational maintenance costs.

Challenges of Current Practices

The Problems of Reactive and Preventive Maintenance

Reactive

- Requires a large stock of spare parts.
- Can result in longer and unexpected plant shutdowns.
- Requires someone to notice the failure and forward the information to maintenance department.
- Inefficient process resulting in longer downtime of the assets.

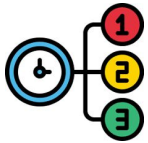
Preventive

- Equipment gets replaced too early: more expensive and unnecessary production stop.
- Equipment gets replaced too late: plant ceases production unexpectedly, potentially unsafe.
- For some equipment, especially pressurised, preventive maintenance is required by law.
- Results in a loss of capacity because this type of maintenance is time or usage based.

The Present

Most petrochemical plants employ reactive and preventive maintenance strategies for the majority of their equipment.

The equipment with most priority is the most advanced when it comes to automation and the use of data.



Most of the plants in the Rotterdam Port area were built after WWII. Therefore, it could be harder to automate older equipment that is incompatible with newer technology.

Plants generate lots of data through different systems, like SAP and CMMS. That data is often not being analysed to implement a predictive strategy.

The Present

Reliability and safety are required before companies invest in new automation opportunities.[16]

Newer and critical equipment are fitted with sensors that gather data in order to monitor its condition and need for maintenance. The equipment most critical to operations are usually the most advanced when it comes to automation and the use of data. [22]

For older equipment, handheld devices are used to gather data. This option is less costly than installing compatible sensors. [21]

Plants generate a lot of data via different systems, like SAP and CMMS.
That data is often not being analysed to implement a predictive maintenance strategy. [16]

Predictive maintenance is becoming more important to implement because of the high outflow and low inflow of knowledge in the industry. [3]

Quotes about the Present

The quotes below are about the present state of automation in the petrochemical industry, expressed by experts with whom interviews were conducted.

- *"The data is already there, start using it"* - **Consultant** [16]
- *"Currently, the company doesn't have systems in place that automatically generate work orders if equipment fails. However, some equipment makes use failure detection alarms. This is mostly true for the more complex equipment that are critical to the process."* - **Technical Service Manager** [21]
- *"Companies do not use their current data/systems correctly."* - **Contractor** [12]
- *"Not all equipment, especially older equipment, is equipped with online sensors and analyzing tools. Therefore, operators of the plant use handhelds"* -**Technical Service Manager** [21]

Quotes about the Present

The quotes below are about the present state of automation in the petrochemical industry, expressed by experts with whom interviews were conducted.

- "*The lifetime of equipment is highly dispersing, which makes it harder to automate a complete plant. It is usually very expensive to buy new equipment, and the costs do not always outweigh the benefits of the newer, more data intense equipment.*" - **Technical Service Manager** [21]

- "*Working with machine data to create work orders is important because of a high outflow of knowledge and low inflow of new knowledge* " - **Consultant** [3]

- "*Before the company invests in any new equipment, it needs to be tested and proven to be reliable and safe (certified).*" - **Technical Service Manager** [21]

Quotes about the Present

The quotes below are about the present state of automation in the petrochemical industry, expressed by experts with whom interviews were conducted.

- *"Preventive maintenance is conservative. You lose part of the capacity of the asset when executing preventive maintenance."* - **Consultant** [22]

- "*We see an increase in the usage of iPads and accompanying apps in the plants when it comes to maintenance. This makes the supporting maintenance processes more efficient, because maintenance employees can enter data directly into the system. It also reduces mistakes, since maintenance employees do not have to transfer data on paper to data in an online system. "* - **Contractor** [12]

- *"Time or use driven maintenance is often based on the expected use of equipment during the following period. An improvement on this would be to gather intelligent data from equipment to interpret whether some maintenance has to be done or not at the time planned."*
  - **Consultant** [22]

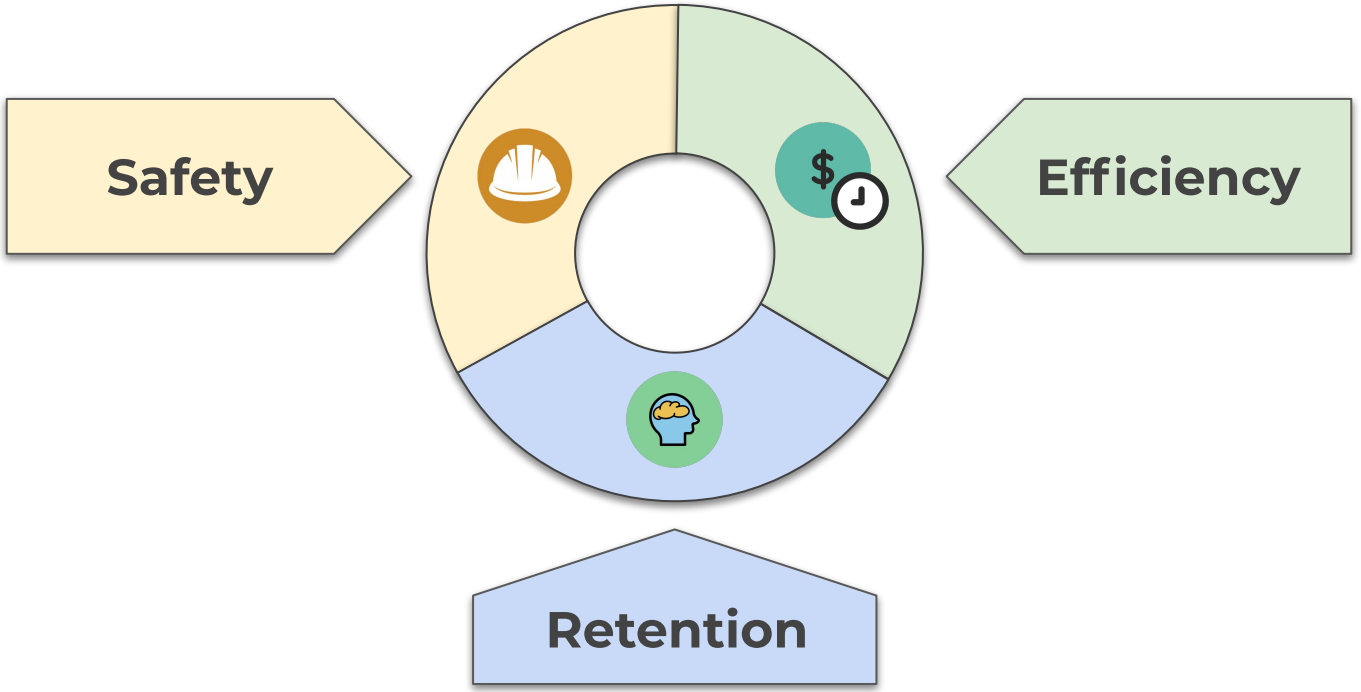
The Framework

The Opportunities and Benefits

The platform is a mandatory component of a bridge. Similarly, articulating the benefits of automation is essential to present a strong argument for its implementation.

Benefits of Automation

Three Categories of Benefits



Benefits of Automation

The Core Safety Benefits [6]

1. Improved alarm management.

2. More accurate detection of defects and inconsistencies.

3. A switch to intervention-by-exception reduces human error.

Benefits of Automation

A Further Explanation of Safety Benefits

Alarm Management [6]

Effective automated systems better organize and simplify the information flow during incidents.

This allows personnel to faster process what is occurring and make better informed decisions in their response.

Human Error [6]

Intervention-by-exception implies that the system operates on its own by default, but requires human input when it cannot perform.

This can involve scenarios where it is either unable to perform a necessary action, or cannot be trusted to make a decision.

This leads to fewer issues arising due to inattentiveness, lapses in judgement, incomplete information etc.

Benefits of Automation

Additional Insights on the Safety Benefits of Automation

When systems are **standardized,** the consequences of **individual differences are diminished** with regards to knowledge, experience, recording habits, etc. This also ensures the system is still **usable when its users change** due to situations such as retirements, new hires and ownership changes. [6]

When automated solutions are also **modular**, they are easier to maintain and specific elements can be **adjusted to adapt to changes** in the environment. Examples include the removal or installation of new equipment, or changes in only part of a process. [6]

Benefits of Automation

The Core Efficiency Benefits

Note: Efficiency includes the resulting cost reductions.

1. Fewer unplanned breakdowns. [22]

2. Maintenance is only done when absolutely necessary. [8]

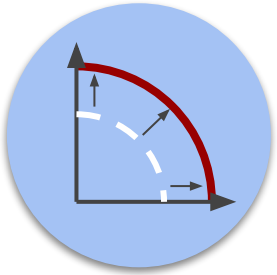
3. Optimized schedules based on preferences (cost, ordering, etc.) [9]

4. Equivalent to having the best operator onsite at all times. [6]

Benefits of Automation

A Further Explanation of Efficiency Benefits

"Intelligent" maintenance extends the **life of assets** and the **mean time before failure** (reliability). This is achieved through methods such as **health monitoring**, which analyzes the condition of components to determine the best time to replace or repair them. This results in the minimum amount of purchases and maintenance events. [14, 21]



It is inevitable that the **productivity frontier** in maintenance practices continues to move forward. Firms should embrace automation sooner rather than later to keep a **competitive advantage**. Failure to do so will allow competitors to capture value instead, and it will prove costly to catch up once it becomes the industry standard. [17, 18]

Benefits of Automation

A Further Explanation of Efficiency Benefits

The automation of maintenance processes allows for the **surpassing of human abilities** as technologies are capable of processing massive datasets and calculating complex simulations. In AI's current state, **human input will still be needed** to verify the best way to use these results. [8]

In essence, automation technologies will not replace employees, but rather enhance their skills. By relaxing their responsibilities on menial tasks, employees can instead **focus on value-adding** tasks that require their unlearnable expertise. The resulting digitalization also **replaces outdated practices** such as record keeping on paper. This allows for information to be retrieved quicker and more accurately. [3, 6]

Benefits of Automation

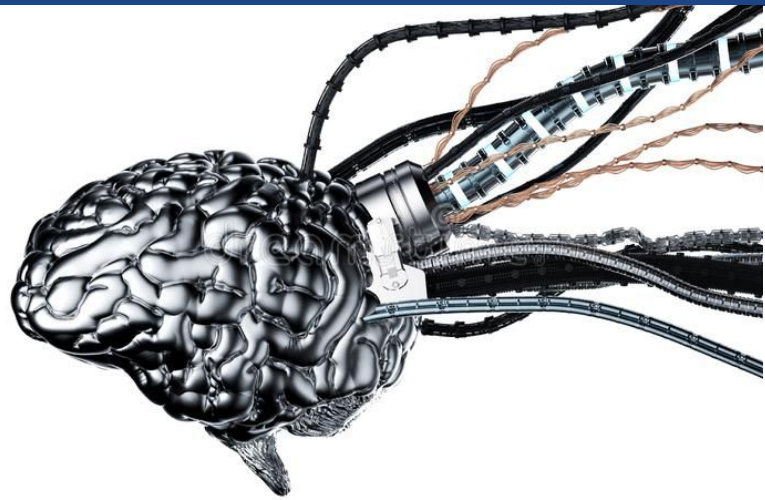
Additional Insights on the Efficiency Benefits of Automation

A recent development of interest to the industry is **augmented reality.** Onsite personnel can transmit the plant environment to specialists through devices such as tablets or smart glasses and receive guidance on activities they are not proficient in.
This negates the need for specialists to travel to the site or be hired full time. It also allows the lesser qualified onsite personnel to gain valuable experience, building their skills and industry knowledge. [16]

The emergence of Big Data also holds significant potential. Especially when cooperating with third parties involved in the entire supply chain, firms can construct digital twins of their plants. These are essentially advanced simulations that allow users to experiment with digital copies to explore reactions, and estimate “future states” that the physical equipment will reach to make automated maintenance even more effective. [14, 16]

Benefits of Automation

The Core Retention Benefits



The knowledge and experience of employees can be **built into automated solutions** if they are able to voice their feedback during the development process. [3]

This provides a **digital knowledge base** where all information is gathered and **accessible for all the departments**, allowing it to become a replacement for information **saved in the minds of workers** or the inefficient way of saving knowledge on paper. [3]

Benefits of Automation

A Soundbite from the Knowledge Roundtable

Clicking on the image below will begin a compilation of audio clips of quotes from the Knowledge Roundtable that discuss the opportunities and benefits of automation.

Quotes about the Benefits of Automation

The quotes below are expressed by experts with whom interviews were conducted.

- *"What we try to show is that it's already there. Lots of companies have data. Lots of companies already have an intranet of things. They're already connected. A lot can be done tomorrow with not so large investments."* - **Consultant** [16]

- *"It starts by mining the gold, the data. And it becomes Internet of Things if you unlock these data for third parties, the number crunchers. You can optimize the automation that you have to go outside the plant fences and try to combine knowledge from other parties in your group to try and find best practices in how to maintain or operate."* - **Consultant** [16]

- *"I think automation is your friend. Doing inspection rounds which is part of the day to day operations is now done on paper. So if you automate the process and your app tells you where to go and what to look for and you can enter the values when you're there, it's automatically put into the CMMS, which gives you realtime information and the opportunity to report incidents or unsafe situations. That increases the productivity of your work"* - **Consultant** [16]

- *"Automation will also help you do the right things at the right moment in the right way. It will help you train people to get them fit for the job. It will increase the time you are active doing what you're good at."* - **Consultant** [16]

Quotes about the Benefits of Automation

Level 3

The quotes below are expressed by experts with whom interviews were conducted.

- *"We have a preventive system. Our SAP system generates standard plans for maintenance automatically. It sends notifications that the preventative maintenance has to be done, which can be initiated by legislation, such as laws that require inspections every few years, or engineers, who think the equipment should be inspected every few years."* - **Maintenance Manager** [13]

- *"One of our priorities for improvement, but we're not all the way there, is digitizing knowledge. We want to avoid having to put anything on paper before it ends up in the system, but rather operators take pictures and insert information about the equipment directly into the SAP system. The scheduling and preparation department could then automatically get this information and make digital work manuals. Then the actual technicians could use tablets with this readily available. This would save time in the process of documenting and the process of sharing information."* - **Maintenance Manager** [13]

- *"We're also trying to robotize several equipment inspections. This would let us avoid having to open and clean the equipment before the manual inspection. It's then also not necessary for workers to get into the equipment, which helps safety."* - **Maintenance Manager** [13]

Quotes about the Benefits of Automation

The quotes below are expressed by experts with whom interviews were conducted.

- *"Discovering new problems during turnaround maintenance which require attention makes the period take longer than expected. Having more data and more information makes the process more efficient. If you know exactly what needs to be replaced you can be prepared and not surprised." -* **Consultant** [20]

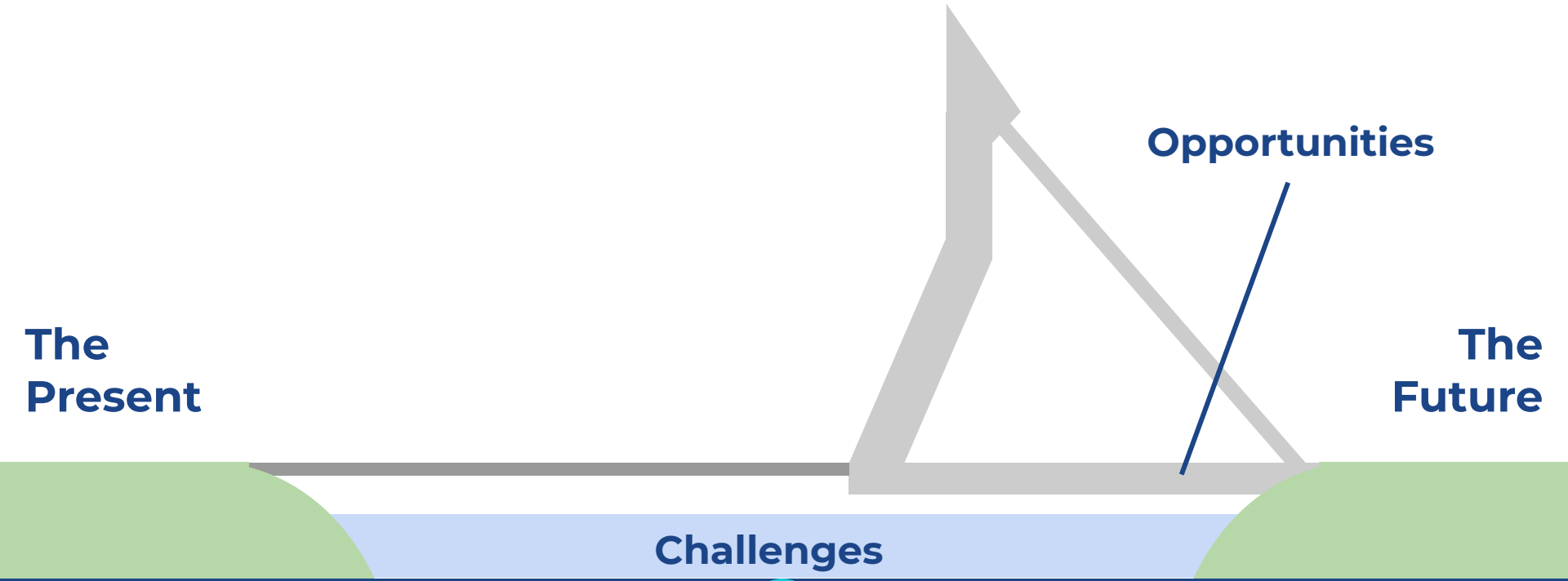
- *"Data labeling looks at error patterns in temperature, for example. This pattern is labeled in a developed tool. We can then build a digital knowledge base, which is the foundation for new algorithms. The algorithms are trained on the identified patterns, after which the pattern can always be identified, giving a warning when this pattern occurs again in the machine. As a result, experts do not have to recognize the pattern themselves. This leaves more time for more complex tasks." -* **Consultant** [3]

- *"Human Machine Interface is changing. We have more data available in the plant to work with. It's readily available to all the people and not only the guys in the office, but also to the people in the field." -* **Technical Service Manager** [21]

The Framework

The Challenges

The road from a present to future state presents some challenges that will need to be overcome.



Challenges of Automation

The Conducted Interviews

During our research, we first conducted interviews with suppliers of automation opportunities. They mentioned the benefits and opportunities of maintenance automation.

Consequently, we could not fully grasp why many asset owners do not automate their maintenance processes. To gain more insight in the challenges asset owners face, we've conducted interviews with a contractor [12] and two employees of a petrochemical company [13, 21] who are affiliated with the maintenance process of the plant.

Challenges of Automation

Level 1

Conservative mindset

Lack of trust & resistance to change

Lack of knowledge

About the benefits, utilization and implementation of automation

Department focus

Focus on operations, and undervaluation of maintenance

Lack of time & resources

To explore and implement automation opportunities

Lack of a strong business case

Added value of automation is not always clear

Lack of proof

Of the reliability and safety of automation opportunities

Compatible options for aging plants

Automation opportunities which are compatible with old assets are not worth the investment

Challenges of Automation

We can roughly divide the challenges into two categories: industry/company constraints and external constraints. Although there is some overlap between these categories, it gives a sense of the major challenges the industry encounters.

The **industry/company constraints** refer to challenges within the petrochemical companies. The challenges imply that asset owners are responsible for solving these challenges themselves.

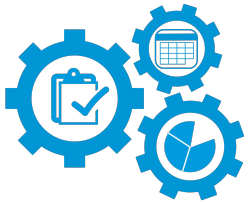
The **external constraints** refer to challenges that are mostly beyond the control of the company. These challenges should therefore be solved with support of external parties.

Industry and Company Challenges of Automation

Level 2

Industry/Company Constraints → **Automation** ← External Constraints

- Due to the **conservative mindset**, asset owners have little trust in the accuracy and safety of automation opportunities. They feel like they can trust their current (less automated) working processes, which makes them resistant to change. [12, 13, 16]
- Due to a **lack of knowledge,** asset owners are not fully aware of the benefits automation offers, and they have no idea how to utilize and implement automated opportunities. [3, 8, 12, 13, 20]
- Petrochemical companies see the operations department as the core of their business and thereby undervalue the maintenance department, which results in unsupportive **department focus** within the petrochemical companies. [8, 12, 22]



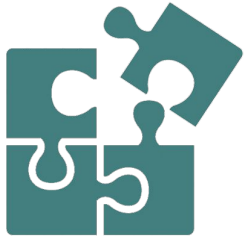
- The maintenance department experiences a **lack of time and resources** to properly explore and implement automation opportunities, which is partly caused by the unsupportive department focus. [8, 12, 13, 21]
- The added value of automation in the maintenance process is not always clear to asset owners, and because there is a lack of time and resources, it is difficult for the maintenance department to explore and identify these benefits in order to build a strong **business case**. [8, 12, 13, 20, 21, 22]

External Challenges of Automation

Industry/Company Constraints → **Automation** ← External Constraints

Safety and reliability are the top priorities of asset owners in the petrochemical industry. Both factors need to be guaranteed for automation opportunities to be considered. However, automation opportunities are **lacking the proof** to ensure safety and reliability. [8, 13, 21]

Currently there is no strong business case for automation options that are **compatible with old assets**. These options are not worth the required investments. [12, 13, 21]



Industry and Company Challenges of Automation

Level 3

Conservative mindset [12, 13, 16]

A challenge mentioned in every interview was the conservativeness of the industry, reflected in a **lack of trust** and a **resistance to change**.

Lack of trust. Asset owners expressed that they don't feel comfortable replacing human observations by automated monitoring because they feel that they cannot be sure of the accuracy of the automated monitoring. Since possible mistakes can increase the chance of safety hazards and reliability problems, asset owners do not want to take the risk.

Due to this lack of trust, asset owners feel that they have to perform tasks twice: both manually and with the use of technological innovation. With the manual observations they "check" the accuracy of the automated results.

Asset owners also fear data leakages when implementing automation. They do not trust the automation opportunities to protect their data sufficiently.

Resistance to change. Asset owners rather stick to the manual procedures they've been using for years because they are certain that they will work properly.

Asset owners also reinforce each other's conservativeness, and when asset owners do not see their competitors automate, they don't feel the need to change either.

Quotes about the Challenges of Automation

Level 3

The quotes below about the conservativeness of the petrochemical industry are expressed by experts with whom interviews were conducted.

- *''There is a lot of fear within companies. They are afraid that if processes get automated/digitized, company data is more likely to end up on the streets. They want to avoid this at all costs. Because of this, they would rather not digitalize any process.''* - **Contractor** [12]

- *''There are many possibilities for improving automation, but we have to note that it is a very conservative industry.''* - **Consultant** [16]

- *''However, a lot of companies are still very conservative and still don't trust the data generated by the sensors. They prefer to open up the equipment to see for themselves if it still works properly. Companies are scared of ''if it goes wrong.''* - **Contractor** [12]

- *''Companies like to stick to the processes they know, because they are to a certain extent sure it will prevent such dangerous situations. They do not know if the new, automated process will be as trustworthy. Due to this resistance to change and the fear of the unknown, maintenance departments and contractors struggle with convincing management about the value it can add.''* - **Contractor** [12]

- *''The industry is quite conservative, because it's dealing with safety issues (toxic chemicals) and robust, global systems where innovation takes a long time.''* - **Maintenance Manager** [13]

Industry and Company Challenges of Automation

Level 3

Lack of knowledge *3, 8, 12, 13, 20*

On a company level, there are some individual companies who are willing to explore and implement automation opportunities. However, when the willingness to automate is there, another problem arises: a lack of knowledge.

Asset owners experience difficulties in knowing what opportunities the market offers and where to begin in automating their plants. On top of that, they experience difficulties with identifying the specific benefits that automation can bring to their plants.

Suppliers stretched the fact that many asset owners possess a lot of valuable data already, but they do not use it well. A relatively simple first step for asset owners would therefore be to analyze and utilize this unused data. However, asset owners lack the knowledge, time and resources to get this off the ground.

Department focus *8, 12, 22*

Petrochemical companies mainly focus on the operations department, which is perceived as the core of the business. Because of this, operations gets assigned the biggest share of the budget and therefore has access to more resources.

Thus, the maintenance department is currently undervalued. Maintenance is a driving force behind operations, and operations relies heavily on maintenance. It is therefore of great important to petrochemical companies to optimize the maintenance processes.

Unfortunately, the maintenance department is not able to optimize their processes if they do not get assigned sufficient resources to explore and implement automation opportunities.

Quotes about the Challenges of Automation

Level 3

The quotes below about a lack of knowledge and an unsupportive department focus are expressed by experts with whom interviews were conducted.

- *''The automation/digitalization level is very low. If there is automation, it is mainly focused on the production process and not on maintenance.''* - **Contractor** [12]

- *''There are many new developments and companies cannot keep up with these developments. This creates a lack of knowledge about what automation does and does not do. Companies don't know what automation can bring them in added value, but they also don't know that automation doesn't make a person able to shut down the entire plant with hitting one button (which is what they are afraid of).''* - **Contractor** [12]

- *''Companies do not use their current data/systems correctly. When asset owners work with third parties who are asked to help with automating maintenance processes, they are often not able to find the information they need because the company's systems are a mess. Because of this, it is really hard to automate these messy systems in an efficient way.''* - **Contractor** [12]

- *''What is also very striking is that production and maintenance are completely independent within the sector. These departments have their own way of working, their own culture, their own levels of automation. Only when there are technical issues production cannot repair, they call maintenance. Maintenance rushes in without having any idea of what is going on. This could be made more efficient if these departments would work together in a better way and become more co-dependent.''* - **Contractor** [12]

Industry and Company Challenges of Automation

Level 3

Lack of time and resources *8, 12, 13, 21*

Asset owners expressed that, even if they want to automate, they lack the time and resources to explore and implement automation opportunities.

One of the causes of the lack of time and resources is the before mentioned department focus. However, a second cause is that automation simply is not top of mind yet. For the current employees there is always something with a higher priority than exploring and implementing automation opportunities.

On top of that, asset owners want these new opportunities to be fully tested on safety and reliability. Obviously, it takes time to fully test new opportunities, time that is currently not available within petrochemical companies.

Lack of a strong business case *8, 12, 13, 20, 21, 22*

A reason why asset owners do not provide the maintenance department with sufficient resources is the lack of having a strong business case.

It is not an easy task to point out and understand the specific value that is being created by incorporating more automation in the maintenance processes. Both suppliers and asset owners recognize this problem.

Because it is difficult to recognize and explain the benefits of automation, convincing management of the importance of automating the maintenance process becomes challenging too.

Due to the fact that management is not putting in enough effort to understand the benefits of automation, it is not possible to create a strong business case in favor of automation.

Quotes about the Challenges of Automation

The quotes below about a lack of time, resources and a strong business case are expressed by experts with whom interviews were conducted.

- *''We have too much other work to do, setting priorities. Last year for example, the priority was the turnaround and preparation for the turnaround. We can't hire more workers spontaneously, there is no approval from higher up.''* - **Maintenance Manager** [13]

- *''We would want to utilize more data, but only if we have more time to look at the reliability of the tools first.''* - **Maintenance Manager** [13]

- *''It is a great challenge for this company to convince asset owners about the added value of an automated maintenance strategy. The business case is a way of convincing companies to invest in automation. Making companies aware of where exactly their costs are and what processes are not efficient enough. [...] To convince companies of investing in a more automated maintenance process, you need to show them where the inefficiencies are and how much money they could save by automating the process.''* - **Consultant** [22]

External Challenges of Automation

Level 3

Lack of proof *8, 13, 21*

A first external challenge is the lack of proof. Safety and reliability are top priorities of petrochemical companies due to the presence of many hazardous substances.

Companies want to be able to guarantee safe working environments for their employees, but they also have to provide proof of safety to the government. Because of this, asset owners demand sufficient proof of the reliability and safety from automation opportunities offered by suppliers.

Asset owners currently state that there is not enough proof, which is an important reason for them not to automate their maintenance processes.

Compatible options for aging plants *12, 13, 21*

Many petrochemical plants in the Rotterdam area were built after World War II, resulting in assets up to 60 years old.

Obviously, modern automation opportunities are not always compatible with these old assets. Even the options that are compatible with old assets are most of the time not working properly and/or not worth the investment.

The old assets are not expected to be operational for a very long time anymore. Therefore, companies are reluctant to invest in automation options that are compatible with these old assets, as these investments would be wasted once the old assets are taken out of service.

Due to this lack of worthwhile investments for old assets, petrochemical companies lack behind in automating their plants.

Quotes about the Challenges of Automation

Level 3

The quotes below about a lack of proof and compatible options for aging plants are expressed by experts with whom interviews were conducted.

- *''The lifetime of equipment is highly dispersing, which makes it harder to automate a complete plant. It is usually very expensive to buy new equipment, and the costs do not always outweigh the benefits of the newer, more data intense equipment. It is an option to upgrade or install additional equipment next to existing equipment, however, this is only done when there is a real benefit in the investment. A real benefit would be safer, more reliable and more efficient equipment.''* - **Technical Service Manager** [21]

- *''Especially in the petrochemical sector, the risk of explosion is very high. Because of this, devices are usually not allowed in the plant because they increase the risk of explosions. There are devices that are made safe for the use near explosion sensitive equipment. However, these equipment are expensive and the maintenance departments struggle with validating the purchase of these kinds of devices. They cannot show management how these devices will return the investments.''* - **Contractor** [12]

- *''When it comes to innovation, it is very important to consider the safety of the equipment. Before this company invests in any new equipment, it needs to be tested and proven to be reliable and safe (certified). Safety is our priority. This does put a limit on using new equipment.''* - **Technical Service Manager** [21]

Challenges of Automation

A Soundbite from the Knowledge Roundtable

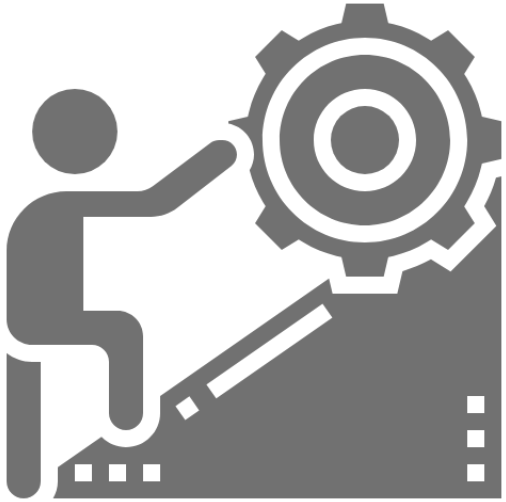
A compilation of quotes and comments from the Knowledge Roundtable [8] about the challenges asset owners encounter when automating their maintenance processes, can be found below.

Challenges of Automation

A Conclusion

External parties like suppliers are responsible for some challenges. However, most constraints fall under industry/company constraints. This means that most challenges need to be faced by companies themselves.

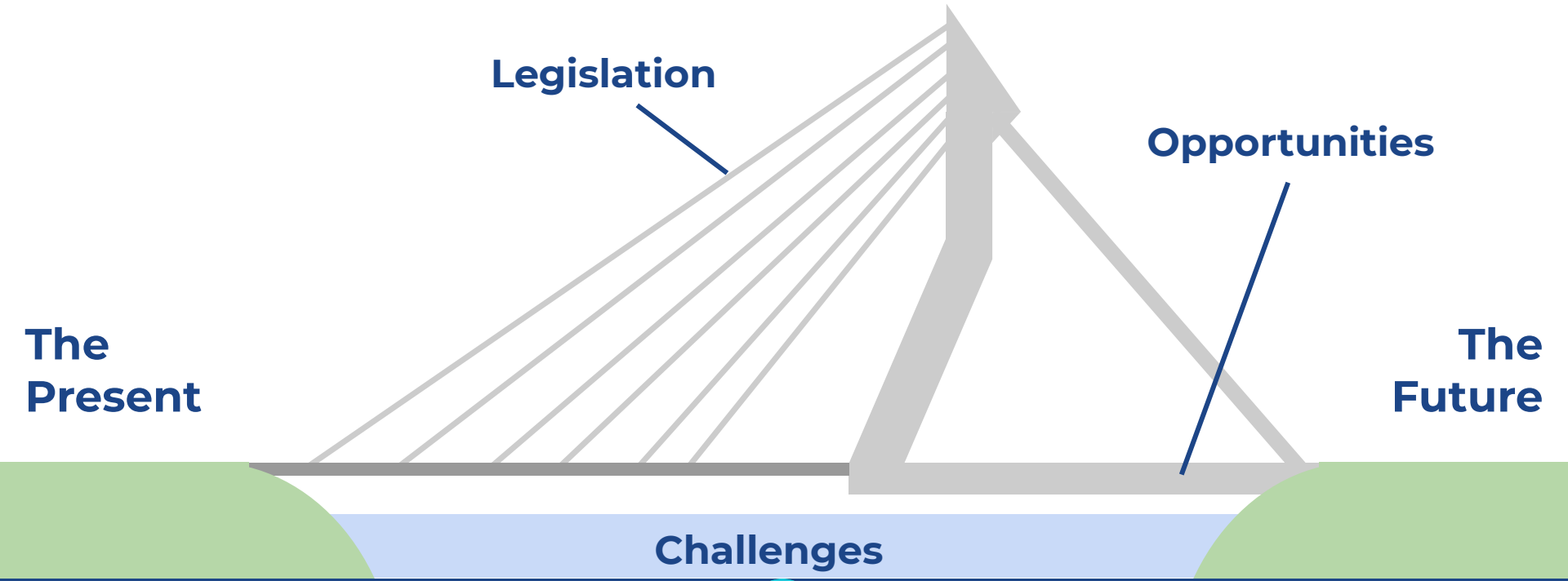
Our suggestions on how to address these challenges are elaborated upon in the recommendations section.



The Framework

Legislation

Legislation can act as a support for the journey from the present to a more automated future.



The Influence of Legislation on Automation

Level 1

Legislation discourages

Legislation encourages

Companies are **required to manually inspect** certain machinery periodically.

- This makes it difficult to justify the investment in technologies that monitor the health status of a machine, as the machine must be taken out of service for inspection, even if the technology reports a healthy status.

The government and labor inspectorate view automation favorably as they believe **people make mistakes.**

- It is therefore an opportunity to boost a company's reputation with regulators, especially concerning safety.

The Influence of Legislation on Automation

Legislation/Regulation Discourages the Use of Automation

- Current legislation and regulations require companies to carry out preventive maintenance and/or regular inspections on some of their equipment, especially pressurised equipment. For these actions to take place, **equipment must be removed from service**. [22, 3, 13, 8]
- For these equipment, investing in sensors and systems to determine their health status makes no sense economically.

Changes required to encourage more automation:

- **Regulatory trust** in the technology and data used to determine a health status must increase. [3]
- **Independent inspectors** must become more flexible and willing to work with predictive maintenance. There is currently a **lack of guidelines** from the inspectors about incorporating innovations, which means that all innovations stay within the fences of asset owners. [13]

The Influence of Legislation on Automation

Level 2

Legislation/Regulation Encourages the Use of Automation

The Buncefield fire

The **automated safeguard** in place to prevent a storage tank from overfilling failed.

- It caused **the UK's largest explosion** since WWII.
- In the Netherlands, it began a real push, led by the labor inspectorate, for technical and automated provisions (despite the explosion being due to a fault with an automated provision). [10]

The opportunity for companies

As regulators view automation favorably, automating some maintenance tasks is an opportunity to regain and **boost a company's reputation** with regulators, especially concerning safety. [10]

- This is useful for companies with **older equipment** as it can **increase the confidence** of regulators that the equipment remains safe to use.

Using automated technology also makes it easier to implement the **requirements of the government** needed to gain and keep the company's environment permit.

The Influence of Legislation on Automation

Level 3

Automation as a Source of Legal Conflict

View of the labor inspectorate

They believe that **people make mistakes** and that machines/automation are more reliable. [10]

- These mistakes in the context of maintenance in the petrochemical industry can have serious consequences for personnel, equipment and the environment.

Disagreements with companies are sometimes resolved in court.

View of some companies

They **trust and believe** in the abilities of their employees to know what's best for their plant. [10]

- Their people are **experienced and knowledgeable** and know the ins and outs of their equipment.
- Regulations must be compatible with all companies and therefore can't be optimal for any one plant.

The Influence of Legislation on Automation

Level 3

The quotes below are expressed by experts with whom interviews were conducted.

Legislation discourages

"Legislation or regulations are a blocker (to automate). Some of the pressurised equipment you need to take out of service for inspection because it's stated" - **Asset owner** [8]

"Companies are obligated to do inspections of equipment that might create dangerous situations when failing. These inspections mean that the equipment needs to be shut down, opened up and inspected. This legislation is quite conservative" - **Consultant** [22]

Legislation encourages

"Our (Dutch) government, led by the labor inspectorate, is really pushing technical and automated provisions because the labor inspectorate feels the human factor is less reliable than the automated/technical factor." [10] - **Lawyer** [10]

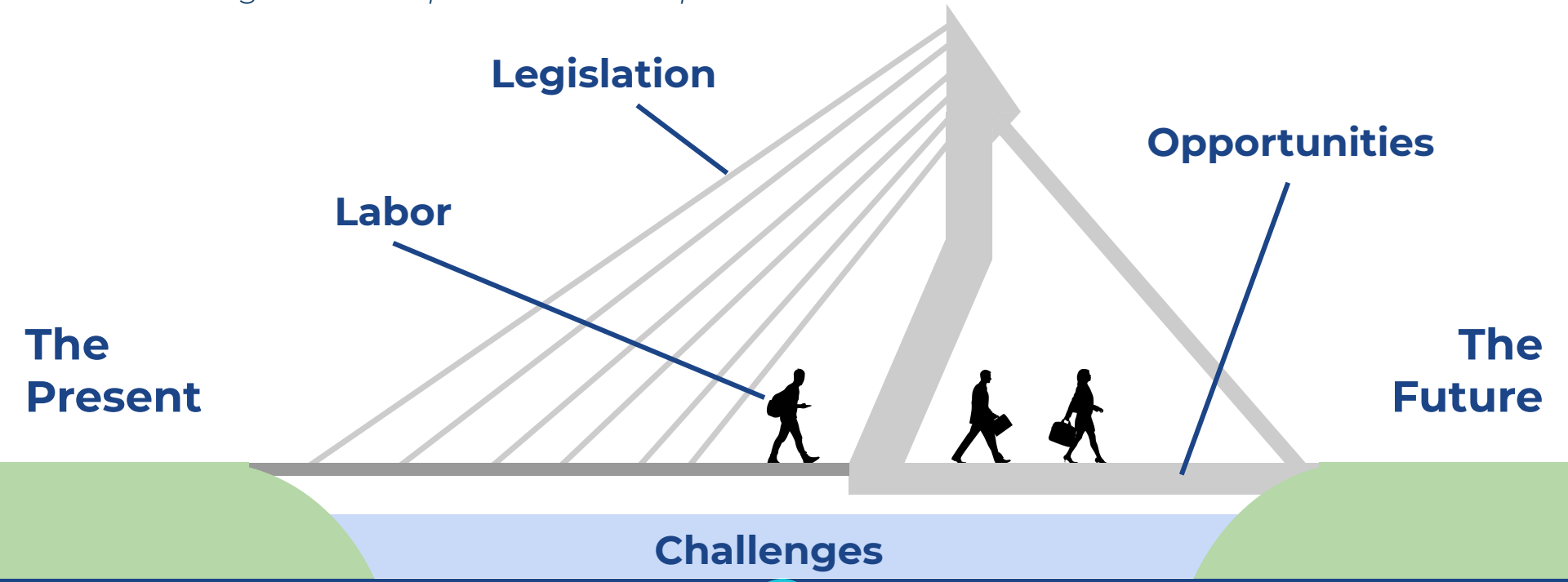
"Automation for the labor inspectorate is an absolute plus. From their perspective, more and more and more automation is an absolute plus." - **Lawyer** [10]

"There will always be an obligation to frequently check if automation is still functioning and to have many fallbacks in place." - **Lawyer** [10]

The Framework

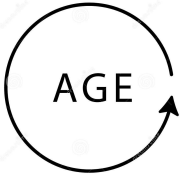
Labor

As a bridge's function is to help people get from point A to B, automation should enable the workforce to go from the present to an improved state of maintenance in the future.



Labor Trends in the Petrochemical Industry

Level 1



Greying Workforce

Current employees leave the industry due to reaching retirement age. Consequently, the industry suffers a brain drain of their knowledge and experience.

Attracting Qualified Personnel

Difficulties in attracting technically and practically schooled personnel leads to a shortage of these requisite skills in the industry.

Retaining Employees

Difficulties in retaining employees since current employees leave due to job dissatisfaction and the younger generations are known for switching jobs regularly.

Labor Trends in the Petrochemical Industry

The Greying Workforce and Retaining Personnel

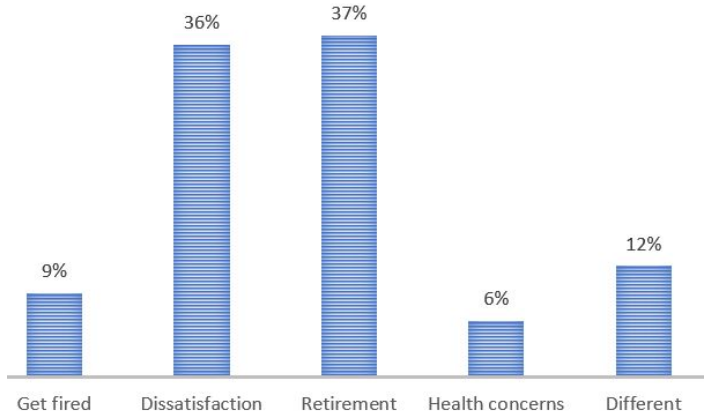


Figure 1: Reasons for leaving the organization [14]

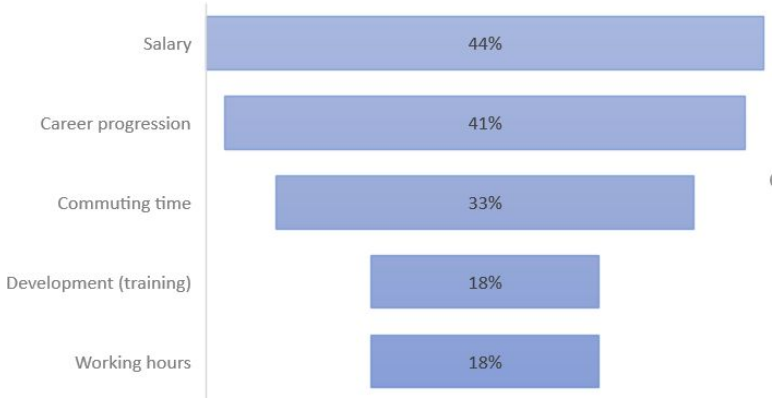


Figure 2: What are employees dissatisfied about? [14]

- **37%** of current employees leave their organisation because they reach **retirement** age. [14]
- **36%** of employees leave due to **dissatisfaction** about their salary, the lack of opportunity for career progression or development, a long commute to work or the lack of time flexibility. [14]

Labor Trends in the Petrochemical Industry

Attracting and Retaining Technically Schooled Personnel

- Only **35%** of the companies in the process industry expected to attract a **sufficient amount of technically schooled personnel** in 2018. [14]
- Retaining technically schooled personnel is expected to be mostly problematic on **MBO and HBO level,** who often perform operational and tactical maintenance activities. [14]
- Retaining **personnel from university** is expected to be less problematic as a result of a growing number of students who chooses a technical education, thus more potential employees. [14]

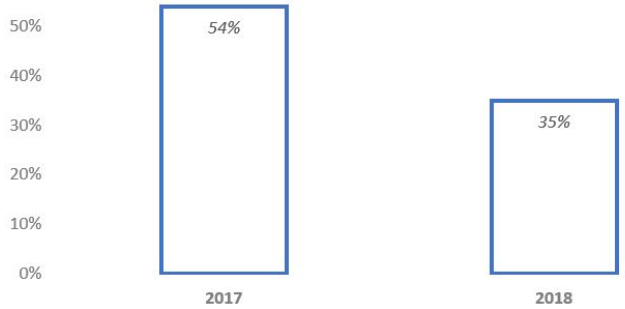


Figure 3: Companies in process industry who expect to attract sufficient technically schooled personnel [14]

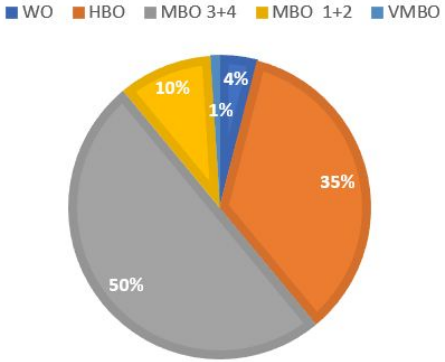


Figure 4: Level on which organisation expect difficulties in retaining technically schooled personnel [14]

Addressing the Labor Trends

The Potential for Automation

Greying Workforce

- Capture current employees' knowledge, competences and actions.
- Store the information in a digital environment, called a knowledge and experience base.

Attracting personnel

- Manual labor only needed for complex maintenance activities.
- Automation as enabler for efficient work execution.
- Digitalization changes the qualifications required.

Retaining personnel

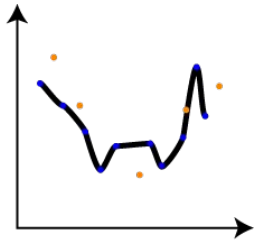
- Automation fosters the increase in the industry's attractiveness.
- Digital knowledge and experience environment reduces the impact of difficulties regarding retaining employees.

Addressing the Labor Trends

Addressing trend 1: Brain Drain due to a Greying Workforce

Option 1: A brain drain [8, 12, 13]
Storing the knowledge of current employees in digital documents and folders.

- Impossible to capture all knowledge in one's head.
- Does not capture employees' actions.
- Information is stored and never looked at again.



Option 2: Combine statistical models with heuristics [3,8]
Collaborate with maintenance experts to identify patterns in the data, making use of Artificial Intelligence, Supervised Learning, Machine Learning and First Principle modeling.

- Not limited to employees' knowledge, it also includes their actions.
- Unable to train for rare accidents such as the Corona crisis.

Option 3: Root Cause Analysis systems [8, 20]
Condition- and health based systems that are able to generate the root cause of a failure or potential failure with a certain percentage of accuracy.

- Necessary to have collected and captured the correct data with techniques such as Artificial Intelligence.

Addressing the Labor Trends

Addressing trend 2: Shortage of Required Qualifications

Automation can replace **modular maintenance tasks,** such as routine physical checks, manual data collection and reporting. [3, 8, 16, 20]

Complex activities falling under craftsmanship will still require manual labor in the near future, but automation enables these employees to perform maintenance activities more efficient, since:

- Personnel can focus on complex rather than modular maintenance activities.
- Condition and health monitoring allows employees to avoid unnecessary tasks and intervene only where needed.

Automation will change the requisite skills for maintenance employees: [3, 12, 13, 20]

The level of technical expertise of personnel will be lowered, because:

- Technical experts can help others from a distance by making use of technologies like Augmented Reality.

Automation will increase the demand for employees with **analytical expertise.**

Addressing the Labor Trends

Addressing trend 3: Retaining Maintenance Employees

How using automation decreases dissatisfaction among current maintenance employees:

- Rise of data analytics fosters **career opportunities.**
- It reduces the **need to commute** by enabling remote support.
- **Retraining employees** to keep up with the latest developments and to develop employees' skills.
- A more **efficient way of working** might reduce overtime and amount of working hours.

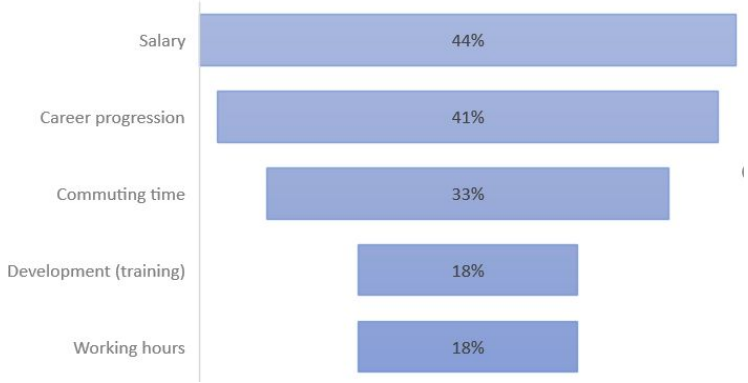


Figure 2: What are employees dissatisfied about? [14]

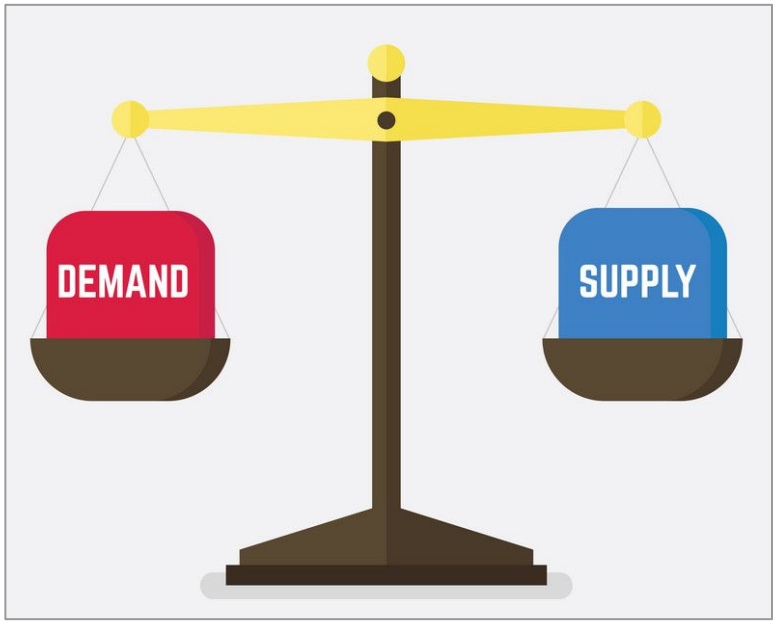
How using automation decreases the impact of younger generations' short-term habits: [8, 12, 22]

- Fastened and more efficient **onboarding process new employees**.
- Working in a more attractive industry due to the rise of data-analytic functions and the associated career opportunities increase the likelihood of retention.
- The indefinite storage of a knowledge and experience base acts as **a way to become more independent** of personnel when retaining employees appears to remain difficult in the future.

Addressing the Labor Trends

Level 3

A Loss of Jobs due to Automation?



- **Using automation in maintenance activities will lower the demand for personnel performing modular maintenance tasks.**
  - With more vacancies open in the maintenance sector compared to the total Dutch average, the loss of functions in the petrochemical industry will not likely result in large-scale layoffs. [14]
  - The near future of maintenance might even come close to a balance of demand and supply regarding personnel. [3, 22]
  - Besides, current employees can be retrained within the company to perform more intelligent maintenance tasks. [20]
- **Personnel with deep knowledge about equipment will still be required,** since complex tasks falling under craftsmanship cannot be automated quickly and without a large investment. [8, 16]
  - Their experience will also be required as support in the training and development of accurate and reliable automated systems. [3, 8]
- **Different types of functions become available** in the petrochemical industry. There will be an increase in demand for people with data analytics skills. [20]

Addressing the Labor Trends

Retraining new employees [20]

Redeploying the workforce into doing more intelligent tasks instead of firing them

- To keep up with the latest developments of automation, the current workforce can and should be continually retrained.
- This is especially pertinent for younger employees, who prefer continuous development of their skills.
- Being experienced and knowledgeable on maintenance processes, this puts current workers in place to derive value from the newest techniques.

Onboarding new employees [12]

The onboarding process can be accelerated by using technological innovations

- Companies could use virtual gaming to let new employees become acquainted with the ins and outs of the plant and its equipment relatively quick.
- This acceleration of training new employees is especially relevant as younger generations tend to switch jobs regularly.
- Virtual gaming can also act as an opportunity for newly hired contractors to become acquainted with the plant.

Addressing the Labor Trends

Old ~~versus~~ and New: Complementary Skills of Generations [8, 22]

Older generation

- Wants to learn about the ins and outs of machinery.
- Knows everything about the equipment in the plant.
- Typically relies on historical data.

Younger generation

- Interested in working with data and technologies.
- Able to read valuable information from the data.
- Typically relies on recent or real-time data.

Quotes about the Labor Perspective

The quotes below about automation and its consequences are expressed by experts with whom interviews were conducted.

- *"By making use of Supervised Learning techniques, experts won't need to recognize the data patterns in the future themselves. This leaves more time for complex tasks."* - **Consultant** [3]

- *"In relatively simple tasks, automation will be an employee's friend. Tasks like flanging however are a craft, and cannot be robotized quickly and without a large investment."* - **Consultant** [16]

- *Condition- and health monitoring leads to enormous efficiency improvements: companies have more insight in (potential) failures in advance. Hereby, you know directly which engineer you need, what equipment he needs to bring, how and when to repair the failure. What would normally be the case is having several employees preparing and inspecting the asset, after which the organization behind the repairs would start. By making use of data technology, the repair process is more time efficient and you need less people."* - **Consultant** [3]

- *"Some skills will indeed become unnecessary, but the current shortage of inflow of young technical professionals in the field won't result in a huge difference compared to the current status. It might even be a more balanced supply and demand of labor forces. On the contrary, if accountants' jobs will be automated, it leads to large scale layoffs. This will likely not be the case in the process industry."* - **Consultant** [3]

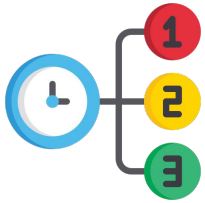
Quotes about the Labor Perspective

The quotes below about generational and interpersonal differences are expressed by experts with whom interviews were conducted or come from magazines.

- *"The new generation technicians, as far as there is one, cannot be educated within the company for two to three years, since Generation Z looks for a new job challenge every 3 years."* - **VAM** [17]
- *"Do not try to educate the current younger generations to become like the current older generation, that will not be possible. New generations won't work for the same company for 40 years until retirement anymore."* - **Consultant** [22]
- *"Today's maintenance professional can never be the data scientist of today, but... Maybe the one of tomorrow."* - **VAM** [17]
- *"The positive side of job hopping is welcoming new employees who bring their knowledge from elsewhere. For some positions, shifting employees might even be beneficial: a fresh look on things."* - **Maintenance Manager** [13]
- *"It will be less necessary to retain different generations, as knowledge is saved in and can be retrieved from the systems."* - **Consultant** [22]
- *"With predictive maintenance, we show that it is fun not to only focus on cost reduction, but also on value creation. Maintenance in combination with new technology, such as robotization and virtual reality, is more sustainable ánd fun. Thereby, younger people become interested in working in the maintenance sector."* - **VAM** [17]
- *"Some employees cannot wait to use digitized technology, while others are practically digital illiterates, not used to working with these kinds of innovations."* - **Maintenance Manager** [13]

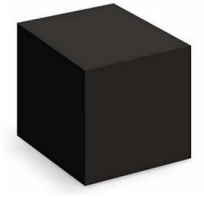
Labor Challenges in Automation

Reasons for the Reluctance to Change Among Maintenance Employees



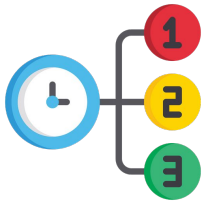
Prioritization of core maintenance activities over supporting innovations.

Maintenance employees **fear losing their status and importance** in the organisation by handing over control to automation.



A black box: trusting the decisions generated by automation to the extent that employees trust their own judgments.

Labor Challenges in Automation

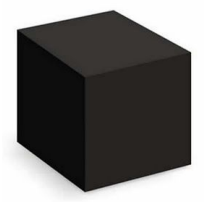


Prioritization of core maintenance activities [3, 13]

- A lack of time results in employees prioritizing maintenance obligations during their shifts, thereby putting the implementation of innovations in maintenance processes second.
- Maintenance employees don't feel the responsibility of supporting the use of automation in maintenance processes.

Maintenance employees fear a loss of status and importance [12]

- Maintenance employees are considered "the heroes who are able to fix anything", which gives them a certain position of admiration and status of importance in the organisation.
- They feel fear of technology replacing their importance and are therefore hesitant to share their knowledge with other departments which they are codependent on for automation to be as beneficial as possible.



The black box of automation [8, 22]

- Maintenance employees feel unable to trust the decisions generated by automation to the extent they trust their own judgments.
- This is due to automation failing to explain them the underlying reason *why* the decision was generated.

Quotes about the Labor Perspective

The quotes below about the labor challenges are expressed by experts with whom interviews were conducted.

- *"We'll need more digital-savvy personnel. For that, we need more trust in what the data tells you, instead of knowing the ins- and outs of a particular machine"* - **Consultant** [22]
- *"Things I often hear from experts when I'm assisting asset owners in their road to automation is 'We've always done it this way' and 'Why would we trust technology when I know this process better than anyone else?'. Current workers don't have the long-term vision that a company needs when looking at the high outflow and low inflow of technical professionals"* - **Consultant** [3]

- *"Asset owners focus on operating their core business, not so much on visionary ideas. Especially in the field - process operators and maintenance employees - innovations are not commonly discussed. It will be discussed in the executive offices."* - **Consultant** [3]
- *"I am open for innovative ideas coming from bottom-up. I think it can be helpful in creating a larger support base for innovation and technological developments among the workforce"* - **Maintenance Manager** [13]
- *"Companies don't know what automation can bring them in terms of added value, but they also don't know that automation doesn't make a person able to shut down the entire plant with hitting one button, which is what employees are afraid of"* - **Contractor** [12]

- *"Employees have to be trained in working with a new tool, you cannot hand them the tool and expect them to work with it. Training takes time, time maintenance employees do not have. Innovation is conflicting with the core tasks on the plant"* - **Maintenance Manager** [13]

A Labor Perspective [8]

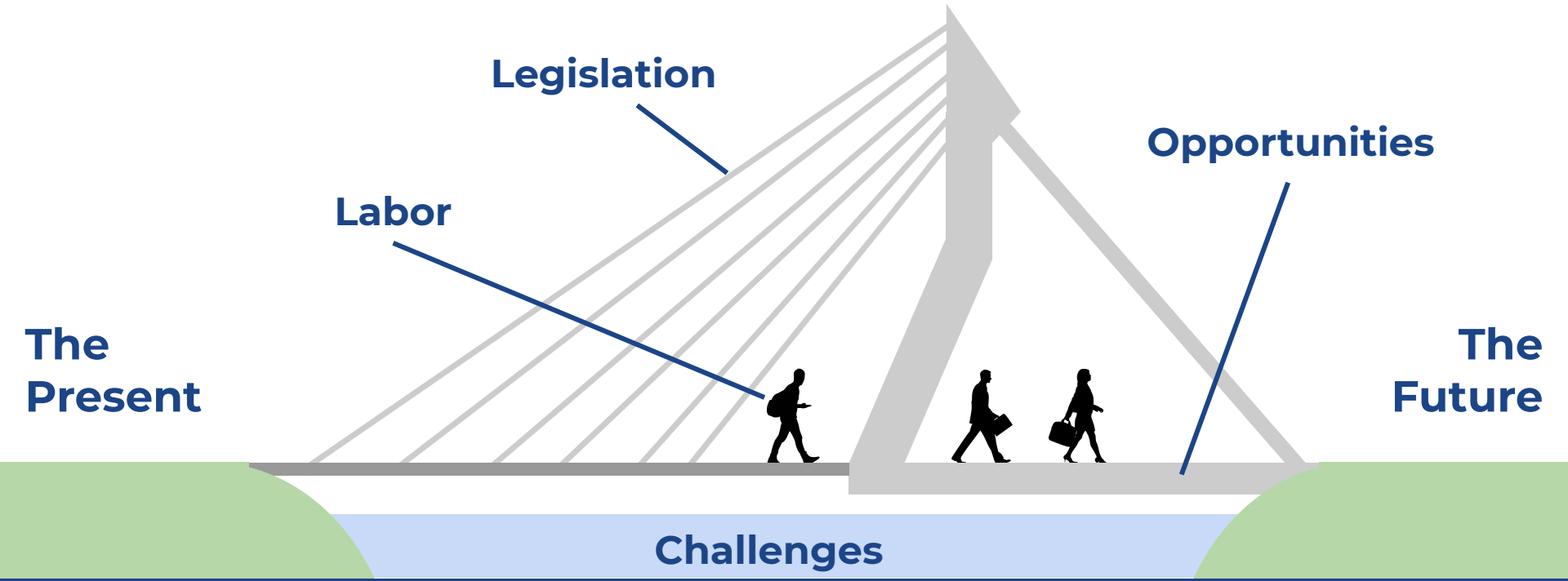
The compilation from the Knowledge Roundtable on the right includes participants' expressions about:

- The trends that the petrochemical industry experiences
- How automation could act as a potential solution for the consequences of these trends
- The soft-side challenges that need to be overcome in the workforce in order to enjoy the opportunities automation offers

The Framework

The Erasmus Bridge as a Metaphor

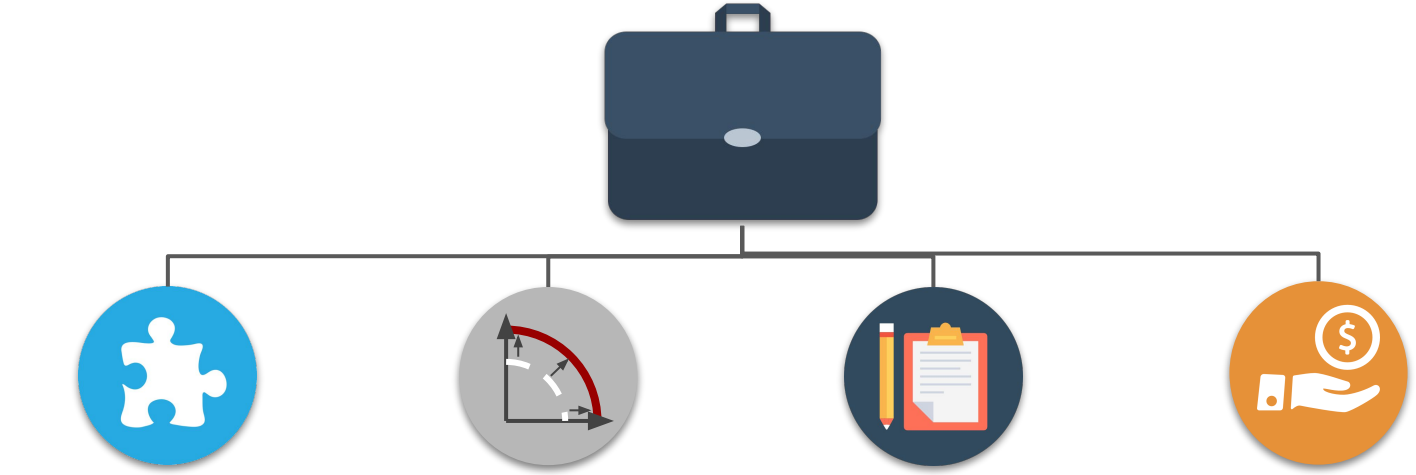
Being able to walk the Erasmus bridge successfully symbolizes the path from the present to a future state of automation in maintenance processes of the Rotterdam petrochemical industry.



Recommendations

Elements of a Strong Business Case

Level 1



A business case is a way of convincing companies to invest in automation, making companies aware of where exactly their costs are and what processes are not efficient enough.

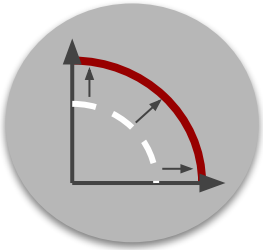
- To convince companies of investing in more automated maintenance processes, one needs to show where the inefficiencies are and how much money or time they could save by automating the process.

Elements of a Strong Business Case

Compatibility

Automation solutions should aim to be compatible with current equipment, or at least avoid impeding upon them.

Keeping Up



Neglecting automation will cost companies the chance to stay ahead of competitors. Automation will eventually become the norm, so it's better to stay ahead of the game.

Proof

There must be concrete proof that automated techniques are safe and reliable before they are implemented across companies.

Cost Benefit

Ultimately, if the economic benefits of automation outweigh the costs, automated techniques will be adopted by companies.

Recommendation 1: Take the First Steps

Level 1

Focus on Operations

Lack of Knowledge

Lack of Time and Resources

Identify the data currently being collected and stored. This requires the assistance of other departments, especially operations.

- Decide what's useful and **what can be discarded.** Start with these data.
- Identify additional data that needs to be collected in order to create real value.
- Explore the possibilities of collecting these data.

These steps help **avoid unnecessary costs** and combat some of the challenges identified before.

Recommendation 1: Take the First Steps

Avoid a backwards approach

Many companies start by **collecting large quantities of data** and then start thinking about how to use it. This causes many problems for companies.

- It results in the wrong types of data being collected.
- It **wastes expenditure** by collecting and storing large quantities of useless data.
- It unnecessarily complicates the entire process.
- It **removes a barrier** to taking the first steps ie. can be seen as too expensive if this approach is proposed.

Cooperate with other departments

When identifying the data currently available, it is important for maintenance to consult other departments, especially operations. It is often the case that maintenance is **unaware of potentially useful data due** to poor communication and disorganised systems.

- Work towards integrating the maintenance department with operations to foster **information sharing and collaboration** between departments.

Recommendation 1: Take the First Steps

Addressing the Challenges

Focus on operations

- Integrating maintenance with operations will **strengthen the trust and collaboration** between departments.
  - This will positively influence the work atmosphere and will result in a better responsibility of assets.
  - It will also increase the level of attention received by maintenance, and ultimately their resource allocation.

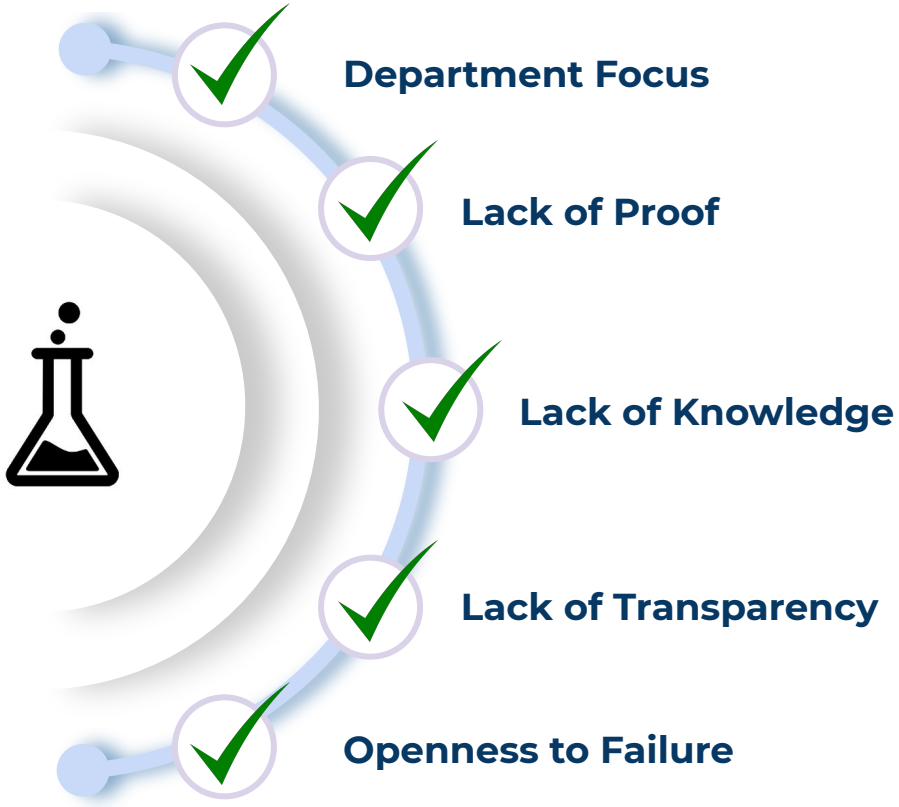
Lack of knowledge

- Taking the first steps to automation will expose the workforce to the potential of automation for maintenance.
  - These first steps can act as a starting point for **developing a knowledge base** amongst employees.
  - Gaps in the workforce's current knowledge can be identified and filled, by internal or external experts/consultants.

Lack of time and resources

- As companies already collect and store data that can be used for predictive techniques, taking the first steps **isn't as expensive or resource heavy** as it may appear.
  - They may be unaware of the data currently being stored by the company and will have to seek it out by collaborating with other departments.

Recommendation 2: Experiment with Pilot Projects



Make use of pilot projects to prove the efficacy of automation for maintenance.

However, ensure these projects are part of a **wider strategy.**

- **Show of and promote** success in these projects to management.

This approach combats many of the challenges mentioned before.

Recommendation 2: Experiment with Pilot Projects

Level 2

Pilot Projects

A smaller scale implementation of a larger project

- Used to work out issues and roadblocks prior to implementing the project on a larger scale.

The purpose

Pilots help companies to manage and minimize risk:

- It allows the project team to examine the effects of automation and to discover unexpected results.
- This experimentation can help to make adjustments to prevent company-wide failure.

The project team

- The team is to be led by a project leader, internal or external of the organization
- Include current maintenance professionals who are enthusiastic about automation:
  - Their enthusiasm creates motivation to work on the project
- Also include critics towards automation in maintenance processes:
  - It allows them to voice their concerns and to see the opportunities of automation firsthand

Recommendation 2: Experiment with Pilot Projects

Level 2

Addressing the Challenges

Lack of collaboration between departments

Automation is not a goal on its own but needs to align with a company's strategy, which requires collaboration between organizational departments.

- Automation can only be beneficial when the whole chain cooperates
  - This stimulates the collaboration between departments in the organization, like Operations, Maintenance and IT.
  - Moreover, it is a reason to improve collaboration between several sub-departments of Maintenance, such as execution, preparation, scheduling and inventory functions.

Lack of proof

Pilot projects can provide proof of concepts, which can act as starting points for well-developed business cases.

- Pilot projects act as an opportunity for companies to examine the effect of automation.
  - With the use of pilot projects, companies are able to determine whether automation provides them with the desired results that could provide the required proof for implementation on a larger scale.

Recommendation 2: Experiment with Pilot Projects

Level 2

Addressing the Challenges

Reducing the lack of knowledge about the benefits of automation

- Pilots are an opportunity for maintenance employees to experience the benefits of automation firsthand, thereby gaining more knowledge about the realistic effects of automation.
- It also creates awareness among employees: automation won't replace their jobs, but is a tool to enhance their efficiency.

Automation as a black box, not anymore

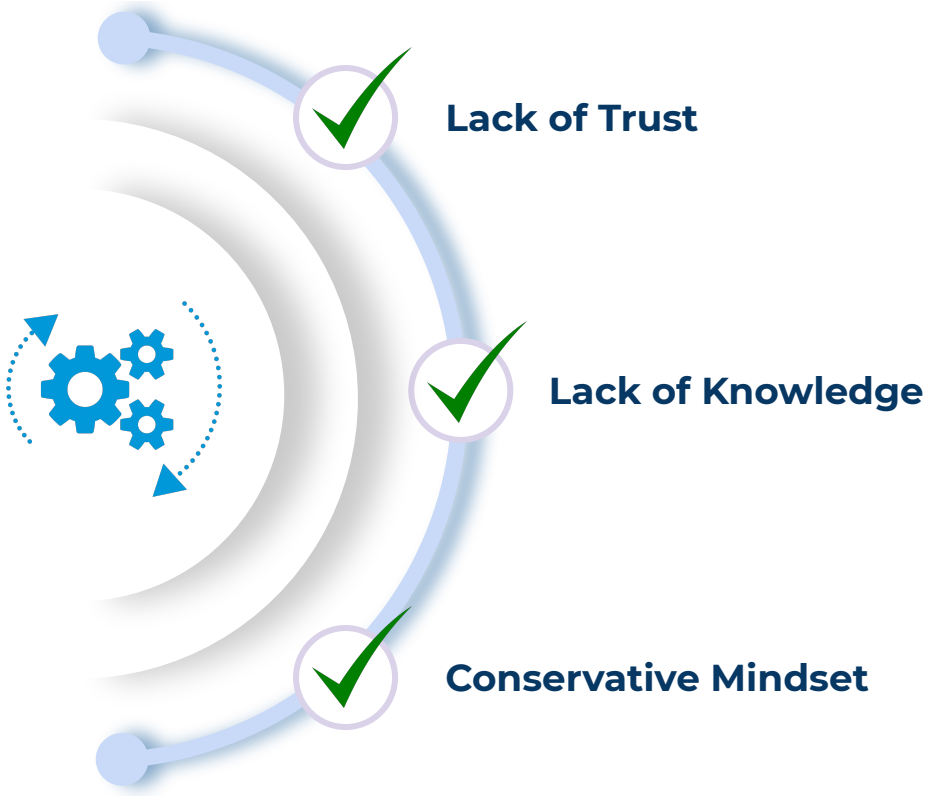
- Throughout the pilot, maintenance workers are stimulated to question the decisions generated by automation systems and to learn more about the underlying reasons of those decisions.
- This will likely result in an increased trust in (the decisions of) automation.

Decreasing the fear of failure

- Pilots are executed in a low impact environment and need a small investment
  - They are therefore an opportunity to increase asset owners' willingness to experiment with automation techniques.
- The pilots also serve as a preparation process to become adjusted to automation implemented in maintenance processes

Recommendation 3: Implement Change Management

Level 1



Implement a **change management process**.

- Educate current workers on benefits and implications of automation

Include experienced workers in the development and implementation of automation techniques.

By educating current workers and engaging them in the process, workers can gain a greater understanding of automated techniques.

This aims to target the challenges mentioned.

Recommendation 3: Implement Change Management

Level 2

Change management throughout the transformation process within companies and industry-wide should include **communication and education** about the intention and realistic effects of automation

- The aim is ensuring that employees feel valued about their contribution during maintenance activities and to **alleviate some of their concerns.**

We further propose to **include experienced maintenance workers** in the development and implementation of automation techniques.

- Their knowledge and experience is useful for the development of a **knowledge and experience base**, enabled by methods like Artificial Intelligence and Machine Learning
- Their **feedback is valuable** for the training of health monitoring systems to obtain higher accuracy and reliability

Recommendation 3: Implement Change Management

Addressing the Challenges

A lack of trust in decisions generated by automated solutions

- By engaging current workers in the development of automated techniques, they are stimulated to **"unbox the black box"** automation is often compared with
  - Experiencing the underlying reasons of a decision generated by automation ("the why's") fosters the trust employees have in decisions generated by automation

The fears stemming from a lack of knowledge

- Educating employees about the realistic consequences of automation regarding employees' activities and ensuring their valuable contribution to the maintenance processes will:
  - Result in workers **acknowledging the purpose of automation:** enhancing their efficiency instead of replacing their jobs or status within the company
  - This will reduce employees' resistance to change, that was caused by fear of the unknown

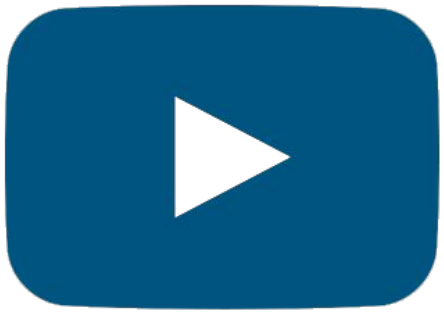
The conservative mindset

- Distrust in automation and a resistance to change due to fear are components of a conservative mindset.
  - Implementing the two soft-side recommendations, the prominent **"We've always done it this way"** will be felt less among the maintenance workforce in the petrochemical industry.

The Future of Maintenance in the Petrochemical Industry

After conducting a literature review and interviews with experts in the petrochemical industry, we organized a digital knowledge roundtable in collaboration with iTanks. Multiple experts were invited to take a seat around the digital table and discuss the future of maintenance with each other.
We provided five statements and facilitated a discussion about them, with Mark Oosterveer from iTanks as moderator. The summarizing video below includes some of the highlights of the knowledge roundtable.

Note: A link to the entire recording of the knowledge roundtable can be found in the reference list. Click the icon below for a summary video.



Participants of the Knowledge Roundtable

- **Frans van den Akker** - Institute for Sustainable Process Technology
- **Johan Enters** - Emerson
- **Giel Jurgens** - Port of Rotterdam
- **Peter Kerkhof** - Shell
- **Ronald de Kok**- MaxGrip
- **Tara van de Lagemaat** - Widget Brain

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The Consultancy Team
Angela van Beek, Leah Berger, David Morahan, Joey Gronovius and Rohit Deshpande

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