Cookbook

Scaling up Smart Maintenance

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1 Introduction

1.1 Why scaling up?

Throughout the last couple of years, many people have performed pilots or proof of concepts with Smart Maintenance. But if you ask yourself, is the scale up already done and is it a great success? And has the potential value been realized? This often seems to be harder than expected!

Our dream is to fully predict all critical events in a plant. Not only for economic reasons, but also to make plants more safe and sustainable.

Our SAMEN team consists of experienced members that have learned a lot by supporting or doing pilots over the past years. Therefore, we know that a lot is possible in terms of technology and knowledge, but we also experienced that scaling up asks other competences and a different approach. Scaling up is another game.

To help companies with the same dream, our team developed an upscaling cookbook. The cookbook is based on real use-cases, involving several types of companies and several types of condition monitoring technologies. The cookbook consists of recipes (process descriptions) and ingredients (requirements) from successful scale-up processes. Of course, you don't have to follow a recipe precisely, you're free (and maybe even recommended) to tailor it your personal preferences. We hope these recipes provide you with ideas for how to successfully scale up Smart Maintenance within your organization.

Do you want this too? Then let's cook!

1.2 How to use the cookbook?

Chapter two describes the recipes of four different scale-up cases from a mix of companies. All recipes have the same structure: setting, starting point, scaling up and results. The cases are from:

A. BP	Asset Owner
B. Vanderlande	OEM / Service provider
C. Perfact (within Tata Steel)	Service provider for asset owner
D. Samotics	Service provider / Start up

Chapter three describes several extra ingredients that were helpful in other cases. With these elements from other cases, you can give extra flavour to the blueprint recipe. The extra ingredients are extracted from the cases:

1. Tata Steel	Asset owner
2. Wemo	OEM / Service provider
3. Sitech	Service provider

The idea is that users of the cookbook recognise there company in one of the cases A to D. Then this case can be used as recipe (blueprint) for your scaling up processes. Additionally, you can add flavour with the extra ingredients.

Chapter four describes the link between the cases and a practical scan, the scalability scan.

Chapter five explains the scan in more detail including an example case. With this scan companies can measure the 'probability of success' of a scale up. The scan gives best practices to improve the success factors for scaling.

Together they represent the recipe for your scaling up!

2 Recipes

2.1 Recipe A – Case BP

Industry	Oil Industry
Assets	Rotary equipment: Pumps, compressors and bearings
Technology	Offline vibration measurements with a handheld device
Organisations involved	BP Refinery Rotterdam B.V.
Departments & functions	Maintenance & Reliability

2.1.1 Phase 0 – Setting

Ever since the 90s, BP has started applying manual vibration measurements to structurally monitor and diagnose their rotary equipment consisting of pumps, compressors and bearings. Over time, BP has installed an increasing number of measurement points onto their equipment. With the use of a handheld device that is placed on these points, vibration data (frequencies) are collected (every six weeks) and loaded into a database. Afterwards, the data is compared to the frequency spectrum in which the asset vibrates in healthy condition. If limits are exceeded, an alarm goes off and the diagnosis of the vibration specialist starts. Experience plays an important role since the vibration specialist has to identify the relation between the vibration patterns and the failure mechanisms in practice. When the problem is known, the vibration specialist and maintenance engineers decide on the appropriate maintenance actions and the priority of these actions.

2.1.2 Phase 1 – The starting point

Monitoring the conditions of assets was initiated by the Reliability department, which supports the repairs, improvements and renewals. They made a selection of the most important assets to monitor and purchased the handheld vibration device. When the employment of the current vibration specialist started in 2007, BP had already installed approximately 240 – 250 different measurement points. The current vibration specialist has a specific view on the value of condition monitoring (he never created a single business case):

“I do not see the real value in announcing when a machine or component is going to fail, surely it is a good thing that you can prevent breakdowns. But for me, the real value is in finding the root causes of failures. If you can modify the components or processes that cause failure, you can get out of the cycle to lengthen the lifetime of machines and improve the reliability of the site, that is where the money is saved. Luckily, BP shares this vision.”

2.1.3 Phase 2 – Scaling up

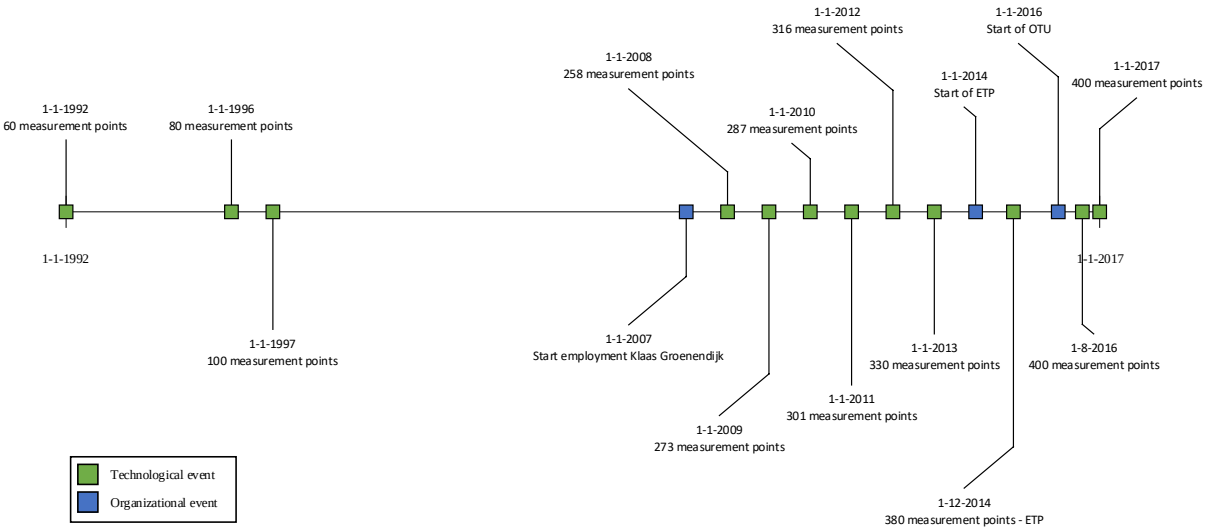
Both before and during the employment of the vibration specialist, the scale-up process has been gradual. Annually (2007 – 2013), approximately 15 measurement points were added depending on the amount of spare time. In 2017, BP was utilizing 1500 rotary machines of which 400 are structurally monitored with manual vibration measurements.

Competence-based trust has played a central role in the scale-up process of BP as the quality of the diagnoses and recommendations of the vibration specialist have strongly affected the available budget and demand for condition monitoring. Over time, the vibration specialist gained experience and trust in several different ways. The specialist attended ISO category two and three training, which improved his ability to understand, explain and visualize the relation between data patterns and failure mechanisms to the maintenance engineers. In addition, the maintenance engineers brought the replaced components back to the specialist which allowed them to check whether the diagnosis was correct. Furthermore, BP has opted for a second opinion several times from external vibration ISO category three specialists. A conclusion that was often drawn, was that the analyses of the specialist were at least equally as good or even more profound than the ones external specialists conducted.

As a result, maintenance engineers asked him to support the turn-arounds and other compelling issues, giving advice on which components to repair, overhaul and replace. Eventually, the vibration specialist was asked to develop the condition monitoring programs for the rotary equipment of two large green-field projects. The first one was in 2014, in which fifty measurement points were added to BP's new Effluent Treatment Plant (ETP). The second project was the Off-gas Treatment Unit (OTU), a large compressor that reduces BP's emission, twenty measurement points were added to comply with the 98% uptime rate set by the Dutch Government. With both of these projects, the budget for vibration monitoring was not an issue anymore.

2.1.4 Phase 3 – Results

When looking back, this case has shown how a vibration measurement specialist from within BP's organisation has evolved into a condition monitoring authority for rotary equipment. Throughout the years, the vibration measurement specialist has established and proven his capabilities and knowledge, resulting in high levels of trust by the management, maintenance engineers and reliability engineers. Although the vibration measurement specialist never created a single business case, he received the freedom to scale up the vibration monitoring technologies.


1-1-1992
60 measurement points
1-1-1996
80 measurement points
1-1-2008
258 measurement points
1-1-2010
287 measurement points
1-1-2012
316 measurement points
1-1-2014
Start of ETP
1-1-2016
Start of OTU
1-1-2017
400 measurement points
1-1-1992
1-1-1997
100 measurement points
1-1-2007
Start employment Klaas Groenendijk
1-1-2009
273 measurement points
1-1-2011
301 measurement points
1-1-2013
330 measurement points
1-12-2014
380 measurement points - ETP
1-8-2016
400 measurement points
1-1-2017
Technological event
Organizational event

2.2 Recipe B – Case Vanderlande

Industry	Process Industry
Assets	Airport Luggage Transport System
Technology	Various: Vibration, Temperature, PLC
Organisations involved	Vanderlande Veghel
Departments & functions	Internal: R&D, Service Development, IT Architect, Service Operations Customer: Airport (IT & Security, Maintenance and Operations) Suppliers: Sensor, IT Capabilities

2.2.1 Phase 0 – Setting

Vanderlande is well-known for its airport luggage handling systems. A typical Vanderlande system starts at the check-in of the luggage, from there it is transported to the screening area where it can either be stored or directly sent to the destined gate. The systems can be kilometres long and consist of conveyors, sorting systems, storage systems and the so-called check-in islands. The transportation of luggage can be considered a critical process. Hub-airports with transfer flights are especially challenging as luggage has to be transported from one aircraft to another in a timespan of under 30 minutes. The stakeholder field with regards to luggage handling systems is complex, luggage issues result in negative chain effects for all parties involved: passengers, airlines, airports and Vanderlande. Ensuring the technical availability and functionality of the systems, therefore, is the key responsibility of the organisation.

For this reason, in 2017, Vanderlande started using condition monitoring technologies to prevent technical failures from happening. Starting with Condition-Based Maintenance had two primary drivers. Firstly, the end-customer (airports) started asking for condition monitoring technologies. Secondly, Vanderlande has to comply with certain service level agreements to avoid penalties. And lastly, the insights of condition monitoring have helped Vanderlande to perform maintenance more efficiently themselves.

2.2.2 Phase 1 – Getting started

The development of condition monitoring technologies within Vanderlande has started small and experimental. In 2019, the service development consultant requested an innovation program together with a co-worker from the R&D department. These innovation programs are meant to launch different proof of concepts to explore the possibilities and tackle the uncertainties for a period of three to six months. To start an innovation program a value case must be presented to the management board to receive approval. When a proof of concept

is perceived as successful additional resources are made available to develop an actual product that can be deployed at a larger scale.

2.2.3 Phase 2 – Scaling up

In the scaling-up process, Vanderlande focuses on several different aspects. The first one is forming a dedicated team with the right knowledge and capabilities involving both internal and external stakeholders: *"A typical team consists of both the maintenance and operations departments of our clients as well as our local team of service technicians, reliability engineers, process engineers, process analysts, data scientists, data architects, data engineers, software engineers and many more."*

Hence, scaling up condition-based maintenance is a multidisciplinary undertaking which makes it extremely challenging. Especially in the beginning, there are many uncertainties with regards to sensors, data, networks and working in the cloud. In addition, the data scientists are located in the headquarters whereas the assets are located elsewhere making collaboration essential to succeed. To accelerate the scale-up process, Vanderlande works closely with start-ups and scale-ups to adopt the newest technologies.

Furthermore, the scaling-up process at Vanderlande depended strongly on the added value that the condition monitoring technology had shown over time. The following example indicates how positive condition monitoring results yield trust among users: *"With the use of condition monitoring technologies we were able to determine the distance between the carriers and the rails on submillimetre level. As a result, the data scientist informed the maintenance engineer to check four abnormal carriers. It turned out that those carriers actually required maintenance. With the naked eye, this would have been nearly impossible to detect for the engineers. In addition, time-wise, it is unrealistic to check the deterioration of 300 carriers daily."*

Besides identifying future malfunctions, condition monitoring technologies are also used to identify the root causes of failure. Vanderlande focuses on creating (automated) feedback loops to provide their suppliers with information on how to improve the quality of their components in the future to increase technical availability.

2.2.4 Phase 3 – Results

Vanderlande has successfully transformed several proofs of concepts into mature technologies. In addition, the use of CM technologies has become a norm within the organization and the service development consultant does not expect that to change: *"When looking at the growing number of passengers, the need for reliable luggage transport will not decrease in the upcoming years."* In addition, new clients increasingly demand integrated condition monitoring technologies when acquiring new luggage handling systems. Vanderlande is willing to grant this request as integrating technologies directly into new luggage handling systems is more efficient and suits their mission of continuous improvement.

2.3 Recipe C – Case Tata Steel / Perfact Group

Industry	Steel industry
Assets	Tubes and gearboxes in plate rolling system
Technology	IoT temperature sensors connected with LoRa network and cloud analytics. The results are displayed in a web-portal based dashboard
Organisations involved	Tata Steel in IJmuiden & Perfact Group
Departments & functions	The maintenance crew of Tata Steel & Two consultants of Perfact Group

2.3.1 Phase 0 – Setting

In November 2019, Tata Steel had acute problems with its plate rolling system. The system transforms large strips of steel into long and thin plates and therefore is an essential part of their 24/7 production process. Unfortunately, it broke down recently costing the company approximately €70.000 per hour. The root cause of the problem turned out to be related to the lubrication of the gearboxes that drive the system. Due to the viscosity of the oil, filth accumulated in the pipeline branches causing congestions that disrupt the oil supply. The detection of these blockages became a structural issue since only the main pipes were provided with flow meters. As a result, maintenance engineers were forced to manually check the pipeline branches every hour. The combination of high breakdown costs, high labour intensity, and safety concerns made Tata's maintenance crew realize that the situation had to be changed.

2.3.2 Phase 1 – Getting started

In March 2020, Tata Steel contacted Perfact Group, a management and consultancy organisation to find a solution. Perfact Group proposed adopting a stand-alone solution consisting of IoT temperature sensors connected to the LoRa-Network with cloud analytics and a real-time webportal-based dashboard. The general logic behind the solution is that the measurement of cold temperatures would be the indicator for congestions. The key benefit of this solution is that sensors could be installed without production stops or complicated IT integrations. Besides the installation time of only "months", the solution was also three to four times cheaper than installing conventional flow meters. For this reason, the maintenance crew of Tata Steel and Perfact Group decided to go for the IoT solution. However, the technology was still in its infancy, and thus Perfact Group was only 80% sure that this solution would work as it was their first time installing it for this purpose.

The maintenance team of Tata Steel deliberately avoided the involvement of the management of the steel company as central top-down decision-making would slow down

the process. First, the technology is still in development scaring the management to invest. Besides, the maintenance crew's own budget was sufficient. And second, the management may have demanded IT integrations with the other systems of the company. In general, such integrations are time-consuming and are not preferred when direct results are desired.

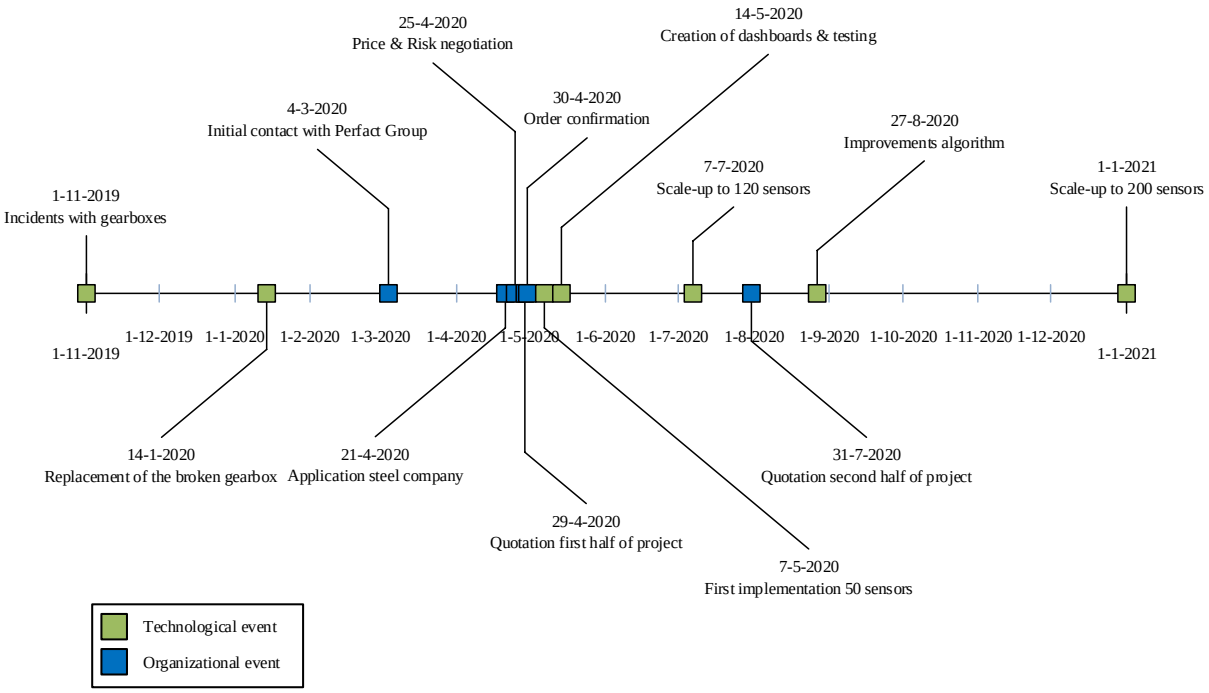
At the end of April 2020, Perfact Group suggested starting with a proof of concept. However, the steel company did not feel much for this and wanted an entire unit to be installed. In the end, the steel company and Perfact Group agreed on a "no cure, no pay" contract, and both parties took a calculated risk with the start of this project.

2.3.3 Phase 2 – First implementation

The installation of the first 50 sensors went smoothly and a week after the installation the first dashboard was created. At the start, the dashboards were a little confusing and the consultancy organisation had the idea that not all of the maintenance engineers understood how to read the data. Therefore, the dashboards were simplified to display the fouling ratio, "0% is good and 100% is bad". Soon a month of testing followed and the temperature sensors indicated the congestions in the pipelines correctly. After every clean-up performed, in the corresponding production stop, the temperatures started to rise and the ratios in the dashboards coloured green again as expected. Due to these developments, the maintenance crew of the steel company started gaining trust in the technology and became more and more convinced of the concept.

2.3.4 Phase 3 – Scaling up

As a result of the increased trust in the technology, the number of sensors was rapidly scaled up to 120 in July 2020. The maintenance crew started reaping the benefits of the technology and used it to generate automatic priority lists for every production stop making it more effective and efficient. After the successful monitoring of the pipes, the steel company tried to extend the application of the technology to the bearings in the system. To enable this function, the algorithms were updated in August. In the next months, the number of sensors almost doubled to 200 in January 2021 and the monitoring of the bearings was successful. Overall, the scepticism towards the technology largely vanished and turned into enthusiasm to implement more technologies in the future.


25-4-2020
Price & Risk negotiation
14-5-2020
Creation of dashboards & testing
30-4-2020
Order confirmation
4-3-2020
Initial contact with Perfact Group
27-8-2020
Improvements algorithm
7-7-2020
Scale-up to 120 sensors
1-1-2021
Scale-up to 200 sensors
1-11-2019
Incidents with gearboxes
1-11-2019
1-12-2019
1-1-2020
1-2-2020
1-3-2020
1-4-2020
1-5-2020
1-6-2020
1-7-2020
1-8-2020
1-9-2020
1-10-2020
1-11-2020
1-12-2020
1-1-2021
14-1-2020
Replacement of the broken gearbox
21-4-2020
Application steel company
29-4-2020
Quotation first half of project
7-5-2020
First implementation 50 sensors
31-7-2020
Quotation second half of project
Technological event
Organizational event

2.4 Recipe D – Case Samotics

Industry	Mechanical & Electrical Industry
Assets	Rotating equipment with AC Motors
Technology	Electrical Signature Analysis with Cloud Analytics (SAM4)
Organisations involved	Samotics
Departments & functions	All

2.4.1 Phase 0 – Setting

Samotics was founded in March 2015 and initially started as a consultancy organization. The idea was pretty straightforward: Analyse the client's data to detect upcoming failures of assets at an early stage. After the first paid assignment in June 2015, the organization quickly started to realise that its business model was full of shortcomings. First, getting access to data was often cumbersome. Second, They also observed a high variety in data formats, which made it difficult to standardise the algorithms. And lastly, the quality of the data usually did not support high accuracy when it comes to detecting failures. Therefore, the organization changed its course and shifted its focus towards building end-to-end products: One integrated offer combining sensors, analytics and a dashboard.

Samotics decided to develop an automated vibration-based system as vibration monitoring is the de-facto standard in the industry. The organisation felt it was better to develop unique technology rather than competing with established players with gigantic R&D budgets. In addition, Samotics learned in the chicken processing industry that practicality matters when deploying IoT sensors in harsh environments. Around the same time, Samotics was working on monitoring railway switches based on sinewaves. What was interesting to see is that Samotics was able to identify issues related to the motor and the switch itself when looking at the signal. This extended the value of the solution beyond the motor to the driven equipment. Moreover, the sensors themselves are installed inside the motor control cabinet, and not on the switch in the field. As such, the solution can be deployed on assets that operate in harsh conditions."

2.4.2 Phase 1 – Getting started

Ultimately, this led to the development of Samotics first electrical signature analysis solution which formed the foundation of Samotics' new business model: Plug & play asset monitoring for critical rotating equipment, delivered as a service. The solution measures electrical signatures (ESA) to monitor the condition, performance and energy consumption of both the motor and the driven equipment. The founder indicates that the performance and energy insights that are provided by ESA are increasingly important when it comes to digital transformation. It offers a foundation to digitize core components of many production processes: The motors, pumps, conveyors and fans collectively make up machines,

production processes, and entire factories. By adding these layers of value, Samotics continually improves the business case for implementing ESA which in turn increases the scalability of the product based on a cost-benefit balance.

2.4.3 Phase 2 – Scaling up

The founder was able to identify different phases in Samotics' journey. The first phase was validating the technology in the marketplace on a small scale. It turned out that there was a demand for Samotics' technology. Many of their "first" clients wanted the Samotics to succeed as they had critical assets performing in harsh conditions that could not be monitored with the currently available practices.

Immediately when the interest in the solution was confirmed by the market, the second phase started. In the second phase, Samotics tried to convert our technological idea into a commercial product. The company started to look for commercially available data loggers that could transform analogue signals into digital signals: *"We could buy them from Texas Instruments and others but their sensors were very expensive as they could do a million things of which we only needed a few."* For this reason, Samotics decided to develop their own sensor in collaboration with the party they knew from the rail project. The fact that sensors with the right capabilities were already commercially available convinced Samotics that the technology risks were limited. The real question was whether they could produce them at scale for a reasonable price. The 1st and 2nd generations of sensors were homegrown and never intended to go to the market. In March 2016, Samotics started with the development of the 3rd generation sensor. The only thing this sensor could do is measure current and send it to the cloud, not incorporating voltage measurements was a real miss. Therefore, investments were made to create a 4th generation sensor. This time, they decided to collaborate with a party named Technolution, arguably one of the best electronics developers. In February 2018, the first 4th generation sensor was deployed with great success at Arcelor Mittal.

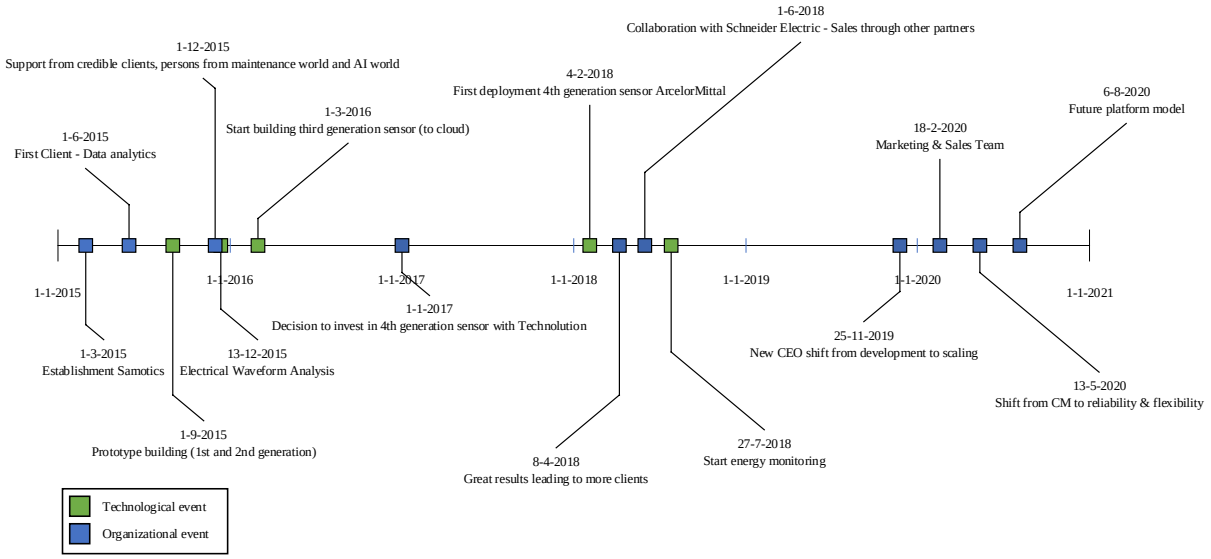
This was the start of the next phase: Optimizing the scalability of the business model. Samotics started with replacing all 3rd generation sensors in the field. *"We went to our clients and told them that we had made a mistake. We can improve your insights with a new sensor that also measures voltage and offered them to replace all 3rd generation sensors for free if they extended the monitoring term to three years instead of one."* All clients agreed to the proposition and Samotics started to deliver valuable results with an 80% detection rate right from the start. While attracting new clients, Samotics gradually improved the detection rate to 92-93%.

Towards the end of 2019, a new CEO was appointed, the start of the last scale-up phase: *"That was a major event in many ways, as we shifted from being a technology start-up that develops a promising technology into a young company that consistently delivers value to our clients."* There was an important reason for this shift. At some point, every technology start-up needs to shift their focus from developing tools to the value that they bring through that technology: How can we help our clients to be more successful? How should we deliver the insights that our technology offers in such a way that it supports our clients' goals? For this reason, the new CEO modelled the company around the customer journey: *"We thought*

about every aspect of our client's experience, as it relates to working with Samotics. From marketing and sales, through implementation, user training, and support. And for every step in that journey, we set up a team with clear objectives and responsibilities to improve the customer journey where possible." Today, Samotics takes a broader view of their work. Their goal remains to help clients to prevent downtime, reduce energy waste, and enable predictive maintenance, but rather than a condition monitoring firm they consider themselves a reliability specialist.

2.4.4 Phase 3 – Results

Gradually, Samotics improved their results: Better sensors, analyses and detection rates have resulted in new clients and increased credibility. Samotics' team grew to a number just shy of sixty employees including marketing, sales and customer service departments and has no intention to stop growing.



3 Ingredients

3.1 Extra ingredients from case Tata steel

3.1.1 Ingredient 1 - Scrum and waterfall method

When implementing condition monitoring technologies for the first time (pilot) the use of scrum may help. The scrum framework itself is simple. The rules, artifacts, events, and roles are easy to understand. Its semi-prescriptive approach helps remove the ambiguities in the development process, while giving sufficient space for organizations to introduce their individual flavour to it. The organization of complex tasks into manageable user stories makes it ideal for difficult projects such as the implementation of condition monitoring technologies. Also, the clear demarcation of roles and planned events ensure that there is transparency and collective ownership throughout the development cycle. Quick releases keep the team motivated and users happy as they can see progress in a short amount of time.

When implementing or scaling up more mature condition monitoring technologies that involve less uncertainty the typical project management approach may be preferred. The waterfall method may speed up the process as standard tasks do not require as much evaluation as new ones. Hence, when starting an implementation or scale-up process of a condition monitoring technology it is important to consider which approach fits best.

3.1.2 Ingredient 2 - Internal Communication (community of practice + newspaper)

Using a community of practice may ease implementing condition monitoring technologies. The community members have a shared domain of interest, competence and commitment to advance condition-based maintenance. This creates common ground, inspires members to participate, guides learning and gives meaning to their actions. Members pursue this interest through joint activities, discussions, problem solving opportunities, information sharing and relationship building. The notion of a community creates the social fabric for enabling collective learning by regular interaction. Communities can be formed internally across sites or countries or can even include external third parties.

Furthermore, it is important make use of short-term wins when implementing or scaling up condition monitoring technologies. According to Kotter, a short-term win is defined by three characteristics: (1) It is clear and unambiguous, (2) It is connected to the change initiative and (3) People can see the results for themselves. Short-term wins matter in change management as employees prefer familiarity in their working processes and are scared to change. Employees are often too busy to engage in changes and only cooperate when they know what is in it for them. Short-term wins can prevent, avoid, and overcome these problems as they show progress and movement. In addition, employees become more motivated, engaged and productive. This helps to maintain the change momentum and prevents change fatique. To successfully incorporate short-terms wins in a condition

monitoring program it is important to set short-term goals and celebrate these goals when completed. Provide the stakeholders with rewards, recognition or social activities.

Source: Book "Leading Change" from J. P. Kotter with the 8 steps change model

3.1.3 Ingredient 3 - Standardisation

Standardisation of condition monitoring technologies may also help to implement or scale-up. The challenge that organisations face is that several different condition monitoring technologies are individually implemented, managed and controlled. As a consequence, it can be difficult to keep the overview and centrally take measures when required. In practice, organisations often overcome these problems by creating "control rooms" to which all individual monitoring technologies are connected (Sitech: Sitech Asset Health Center & Tata Steel: Asset Monitoring & Diagnostics Center) or through building an application that integrates all condition monitoring technologies.

3.2 Ingredients from case Wemo

3.2.1 Ingredient 4 - Management Support

Having the support of the management is essential for the implementation and scaling up processes of condition monitoring technologies. Success strongly depends on the provision of the required resources in terms of workforce and budget. In addition, the management has the ability to put condition-based maintenance on the organisation's strategic agenda. This helps to create awareness and a strategic vision to implement and scale up condition monitoring technologies. Furthermore, business cases of condition monitoring technologies are often uncertain as the benefits are often scattered and hard to capture. In these cases, management support can prevent delays in the implementation or scale-up.

3.3 Ingredients from case Sitech

3.3.1 Ingredient 5 - Technology champions

Implementing and scaling up condition monitoring technologies is not simply a matter of overcoming technological barriers it rather is the introduction of a new culture and way of working. These changes often cause resistance within the organisation as employees prefer to stick to their known work processes. By using technology champions, individuals who are actively engaged in using technology often and consistent, the resistance can be reduced. Technology champions can act as peer references for the positive learning outcomes that can be achieved by utilising new tools, as well as being prime candidates to mentor colleges and organise workshops. Training from peers in the form of technical assistance or recommendations act as a key factor affecting the decision to adopt new technology. Technology champions are trusted sources of information that are able to show, through experience, the process steps for using a condition monitoring technology, and can provide tips and tricks that prevent colleges to fall back into their old habits.

4 From recipes to quick scan

As mentioned before, the recipies are for inspirational purpose for your own project for scaling of smart maintenance.

The next table is a summary of all cases in line with the four topics scan of the next chapter.

Relevant elements from recepies (cases)				
	Case PB	**Case Tata/Perfact**	**Case Vanderlande**	**Case Samotics**
Resources and knowledge	Budget for one expert, enough to start the journey	Budget, knowledge and materials were available.	Started small, later scaled up.	Idea with impact, help from investors
Impact & Motivation	Organic growth of the application	Added value was very clear and large. Sense of urgency was there.	Initiator was customer. R&D team picked it up.	Opportunity: many e-motors to scale
Technology	Handheld bearing condition monitoring system. Proven technology, first step for future smart applications.	Combination of low cast IoT sensors with algorithms. New application, therefor first some tests to proof solution. Not yet a system integration (stand alone)	Experiments tested with various technologies	Existing technology, but not much applied. This technology combined with special sensor and artificial intelligence
Organizational change	Expert won the trust of the team and this was basic to grow.	Support on the level of department and in line with business strategy.	Lot of effort from project team together with customer. Also starting point to Servitization.	Grow from 10 to 30 employees and from pilots to scaled solution.

Relevant elements from extra ingredients					
	scrum/waterval	**Community of practice**	**standaardisatie**	**Management support**	**Technology champion**
Resources and knowledge				Necessary to make resources available	Necessary to have someone how can secure the knowledge
Impact & Motivation					Can make business case easier
Technology	In case technology is not yet proven or mature, this is good approach.		Necessary to scale the solution		
Organizational change		Positive impact on change		Nodig voor duurzame change	Can give energy tot he team

5 Scalability Scan ('taste test')

To judge if your finished pilot project is ready for scaling, we developed a scalability scan. The outcome of the scan gives advice were to improve or even to stop the project.

5.1 Best practise scores for scalability scan

In this matrix all elements are listed with the best practice score and advised action:

Best practise elements for scaling		
	Best practice score	**Action (intervention)**
Resources and knowledge	• budget allocated in line with business goals and annually reviewed. • skills and knowledge of all functions are continuously updated and improved • Available hard & software, Level 1-3, connectivity, datawarehousing, IT infrastructure	• Proactive, global (not department only) • Give training, hiring, contractors • Substitutes, other manufacurer / supplier
Impact & Motivation	• Company wide business cases based on specifications and data and attractive ROI • Impact on licence to operate/ high influence of regulations statutory/mandatory assessment and impact on maintenance strategy • high impact events are standard evaluated against smart maintenance opportunities.	• Get support in making business case • Integrate in asset management policy • Use failure data to create sence of urgency
Technology	• Sensor catalogue (standard) is continuously updated and assessed against scalability, security and benefits. • Connectivity infrastructure is continously updated to improve scalability and security. • Data storage and analytics solutions are continously updated to improve scalability and security. • User interface is continously updated to improve scalability and security. • Systems are designed and selected in an optimal way with integration in mind.	• Standardize (or check) method / technology first
Organizational change	• Integrated teams with clear decionsion criteria • Smart maintenance strategy is clearly linked to organisational strategy. It is cascaded down in the organisation. • Enterpreneral growth mindset foster rapid adoption of smart maintenance innovations. • Technology champions are encouraged and rewarded to develop and deploy new ideas in smart maintenance. • Management is engaged in and visibly supports and communicates about smart maintenance developments	• Introduce Program board • Search for highest fit or triggers as starting point • Awareness sessions and create community of early adapters • Facilitate and involve champions, award new heros • Early involvement of management, stakeholder engagement

5.2 The Scalability scan in more details

To measure the probability to success we developed a scalability scan. To maximize the probability of success, it is needed that **ALL** elements have a positive score. In case one element is week, then this will have impact om the scaling journey.

The scan is not yet validated on large scale, but with our today's insight we advise to reach a minimum score of 70% of 100% per area.

5.2.1 How to use scan

Our advise is to do a first scan to test the 'success factors' of a project idea (scores in column 'start') to find the weak spots and try to improve these area's before starting the project with the advise in column 'actions to improve'.
The next step is to do a second scan (column 'Deploy') to check if the scores are sufficient to have a bigger chance of a successful scale up.

5.2.2 Example

To show an example scan we use the Tata Steel / Perfact Group case. As you see is the 'start' score of 'technology' to low. Before the start of the project two actions were taking:

1. Do a small pilot measure to assure that the concept solution works
2. Put in the contract a 'no cure no pay' part to give extra trust to the customer

The other 'weak spot' about the integration the customer excepted, because the 'time to monitor' was more important than the integration in the future.

Scalability Scan Smart Maintenance
Appendix Cookbook Scale up Smart Maintenance

Project: Perfect/Tata case

Category	Ingredients	reference 1*	reference 5*	Action to improve	SCORE [0-5] Start	SCORE [0-5] Deploy	Actions Start %	Actions Deploy %	Actions And/or comments
Resources & Knowledge	Budget available (for implementation & operation)	no budget, other priorities	budget allocated in line with business goals and annually reviewed.	Proactive, global (not department only)	5	5	100%	100%	
	Skilled people available (for implementation & operation)	no resources or no knowledge of smart maintenance	skills and knowledge of all functions are continously updated and improved	Give training, hiring, contractors	5	5			
	Material available (for implementation & operation)	Lack of material: hard & software (sensoring, IoT, platform, logging), infrastructure	Available hard & software, Level 1-3, connectivity, datawarehousing, IT infrastructure	Substitutes, other manufacurer / supplier	5	5			
Impact & Motivation	Positive business case (or value) from safety, availability, quality, sustainability, ...	negative or no (business) case	Company wide business cases based on specifications and data and attractive ROI	Get support in making business case	4	5	90%	100%	
	Demanded by regulation/client/head quarters/...	no influence of regulations	Impact on licence to operate/ high influence of regulations statutory/mandatory assessment and impact on maintenance strategy	Integrate in asset management policy	0	0			
	Sence of urgency from event (example: corona, recent failure)	no event as trigger, no awareness	high impact events are standard evaluated against smart maintenance opportunities.	Use failure data to create sence of urgency	5	5			
Technology	Scalable, secure and proven sensoring	Not scalable or not secure or not proven	Sensor catalogue (standard) is continuously updated and assessed against scalability, security and benefits.	Standardize (or check) method / technology first	2	5	64%	88%	
	Scalable, secure and proven connectivity	Not scalable or not secure or not proven	Connectivity infrastructure is continously updated to improve scalability and security.	Standardize (or check) method / technology first	5	5			
	Scalable, secure and proven data, storage+analytics	Not scalable or not secure or not proven	Data storage and analytics solutions are continously updated to improve scalability	Standardize (or check) method / technology first	5	5			
	Scalable, secure and proven user interface	Not scalable or not secure or not proven	User interface is continously updated to improve scalability and security.	Standardize (or check) method / technology first	2	5			
	Integration systems	Stand alone, no data warehouse integration	Systems are designed and selected in an optimal way with integration in mind.	Standardize (or check) method / technology first	2	2			
Organizational change	Number of independent decision-makers	large group of various departments and silos.	Integrated teams with clear decionsion criteria	Introduce Program board	3	3	72%	72%	
	Organizational fit (in line with strategy/KPIs/processes/...)	No organisational or strategic fit, no line of sight	Smart maintenance strategy is clearly linked to organisational strategy. It is cascaded down in the organisation.	Search for highest fit or triggers as starting point	5	5			
	Cultural fit and change readiness (reliability/asset management/digitization culture, people see added value of predictive	Traditional, very conservative, risk avoiding.	Enterpreneral growth mindset foster rapid adoption of smart maintenance innovations.	Awareness sessions and create community of early adapters	4	4			
	Influence of technology champions	negative influence	Technology champions are encouraged and rewarded to develop and deploy new ideas in smart maintenance.	Facilitate and involve champions, award new heros	4	4			
	Management support	no support or negative influance, not involved	Management is engaged in and visibly supports and communicates about smart maintenance developments	Early involvement of management, stakeholder engagement	2	2			

The result of the actions in this use case lead to an improvement of the score from 64% to 88% in the area of technology. The scores visualized in a graph: