# 8

# Business Models: Proactive Monitoring and Maintenance

**Michel Iñigo Ulloa[1], Peter Craamer[2], Salvatore Esposito[3], Carolina Mejía Niño[1], Mario Riccardi[3], Antonio Ruggieri[3], and Paolo Sannino[3]**

[1]MONDRAGON Corporation, Spain
[2]Mondragon Sistemas De Informacion, Spain
[3]Ansaldo STS, Italy

As stated by Brisk Insights market analysis [Brisk Insights, 2016] the global operational predictive maintenance market will grow at a CAGR of 26.6% within 2016–2022, foreseeing a total market value of 2.900 million by the end of such period. This will be certainly boosted by the IIoT market rise, which is growing at a CAGR of 42%, and will act as an enabler for its rapid industrial penetration. One of the key sectors (among all industries), in which predictive maintenance will make a huge difference will be manufacturing. The European manufacturing sector accounts for 2 million companies and 33 million jobs, representing the 15% of the total European GDP. With the aim of increasing this contribution to 20% by 2020, European manufacturing industry faces a huge but promising challenge, given industry's potential in jobs and growth creation. However, industry's share in the European GDP has declined during the last years, mainly due to a deceleration of global investments, market uncertainty and production offshoring to low-cost countries. This applies to all actors of the manufacturing value chain, involving production asset end users, asset manufacturers and asset service providers.

In order to cope with that, the full digitization of European industrial ecosystems has been stated as the foundation upon which competitiveness goals will be achieved. Within this framework, predictive maintenance accounts for a huge improvement potential to all actors mentioned: relevant productivity increase (asset end users), new revenue streams with higher profit margins (asset manufacturers) and new business opportunities based on analytics (asset service providers). According to McKinsey, predictive maintenance in factories could cut maintenance costs down by 10 to 40 percent, leading to manufacturers savings of 215 to 580 Billion€ in 2025 [McKinsey, 2015], resulting from reduced downtimes and minimized manufacturing defects among others. Despite this clear potential, maintenance strategies in place still rely on ineffective corrective and preventive maintenance actions, which have a high impact on productivity (higher production costs, delays on delivery, customer dissatisfaction, etc.). Not only available shop floor data and production assets behavior knowledge is underutilized, but also new businesses generation along the value chain is heavily hampered.

Regarding technology, there are several reasons behind the lack of adoption of predictive maintenance across European industries:

- **Production systems complexity:** the majority of European industrial facilities is shaped by very heterogeneous assets, being the asset end user unable to gather deep knowledge about the behavior of each asset (expertise often retained by the asset manufacturer);
- **Lack of interoperability among different assets:** afraid of the possibility of having a $3^{rd}$ party providing services on their production assets, asset manufacturers often apply vendor lock-in solutions to their products. This results in a huge IT integration work required to connect them, usually preventing end users from implementing predictive maintenance solutions;
- **Non-reliable prognostics estimates at a system level:** even though successful prognostics applications have been deployed at component and sub-system level, asset end users interest focuses on increasing the availability of the whole system, which has a direct impact on competitiveness. Thus, the lack of real prognostics and health management systems demonstrated at industrial level derives from a reluctance in early adopters.

In order to overcome those limiting factors, there is a clear need of bringing together all value chain actors (gathering real-time data, asset behavior knowledge and analytics expertise); as well as taking advantage of advanced analytics technologies already applied in a wide range of sectors. This will enable to match predictive management system capabilities with real industrial needs, achieving downtime minimization and OEE maximization at a system level. Besides all above, several non-technological challenges (such as corporate culture) prevent the penetration of predictive maintenance technologies across industries. This applies especially to SMEs, being the most relevant the following challenges:

- **Uncertain RoI:** industrial CAPEX plans are fully subject to their expected profitability, usually in a short-term (depending on the company's balance sheet, often 2–3 years). Since the implementation of such predictive maintenance systems may imply investing in data acquisition, industrial communications and advanced analysis technologies (mainly regarding old production assets), companies often opt for more profitable investments (e-g purchasing new machinery, which leads to a direct productivity improvement);
- **Required skills:** despite the high level of automation in place in most of the European industrial companies, the implementation of Industry 4.0 (within which predictive maintenance is located) is currently requiring a shift from classical operators to highly analytical profiles. Industrial HMIs usually do not take advantage of available technologies such as adaptability, self-learning features, etc., resulting in workers frustration by not showing the right information to the right people.

## 8.1 Maintenance Present and Future Trends

Ever since asset failures have caused downtimes and extra costs, accidents or inefficiencies, businesses have supplied material and human resources to minimize their impact and avoid their re-occurrence. These resources have been different depending on a) the harm to be avoided, b) impact on the balance sheet and Profit & Loss Statement, or c) competitive threats that hinder business survival causing very different grades of implementation depending on the sector and the type of asset.

Current approaches try to preserve function and operability, optimize performance and increase asset lifespan with optimal investments. This approach is the result of a significant evolution through time. According to some authors, four maintenance generations can be distinguished and each represents the best practices used in particular periods of history, as depicted in Figure 8.1 or Figure 8.2, both from [Cristián M. Lincovil B and G. Ivonne Gutiérrez M, 2006]

Towards the end of the 90s, the development of 3rd generation maintenance included:

- Decision-making tools such as risk management and error analysis;
- New maintenance techniques like condition monitoring;
- Design, with special relevance on reliability and ease of maintenance;
- Wide-reaching organizational changes looking for employee input, teamwork and flexibility.

The new approach of the fourth generation is centered on failure elimination using proactive techniques. It is no longer enough to eliminate failure effects but to pinpoint the root causes of malfunctions and avoid their re-occurrence.

Additionally, there are growing concerns about equipment reliability and thus maintenance is gaining more relevance starting from the design phase of the project. Also, it is very common to implement continuous improvement systems regarding preventive and predictive maintenance plans, applied to the planning and execution of maintenance.

Apart from the mentioned characteristics, there are other aspects whose importance had gotten considerable greater:

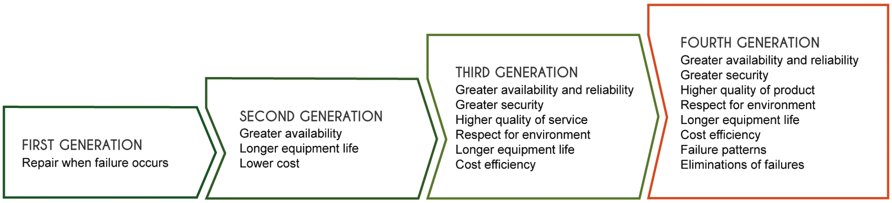



**Figure 8.1** Main maintenance objectives evolution [Cristián M. Lincovil B and G. Ivonne Gutiérrez M, 2006].

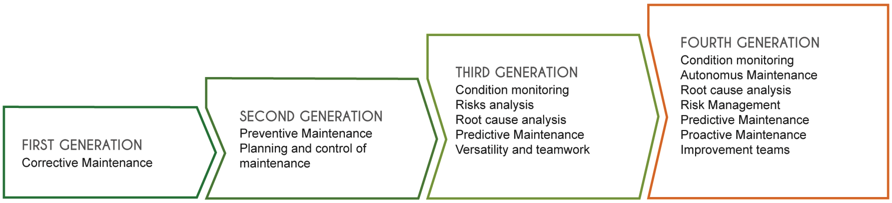



**Figure 8.2** Evolution of maintenance techniques [Cristián M. Lincovil B and G. Ivonne Gutiérrez M, 2006].

- **Risk management.** The identification and control of possible incidents that have low probability but high impact (especially in high-risk industries) was gaining more relevance. The role of maintenance is key in this process and there are concerns that methodologies in use for "low probability / high impact" incidents are not effective, so new methodologies have to be developed;
- **Failure patterns.** Traditional thinking about the link between machine aging and malfunction is being shifted. In fact, there is evidence for some equipment that there is a low correlation between operation time and failure probability. The rate of machine failures can be represented in a bathtub curve (Figure 8.3) that shows that there are more probabilities of early and wear-out failures. [Arnold Vogt, 2016].

Proactive maintenance consists of a step beyond when aiming to reduce failure probabilities. The main focus of proactive maintenance relies on eliminating failures, not their impact. For this purpose, root causes have to be removed, which requires deep knowledge of the system. Some tools like RCA are helpful although they are often used as reactive tools rather than proactive ones.

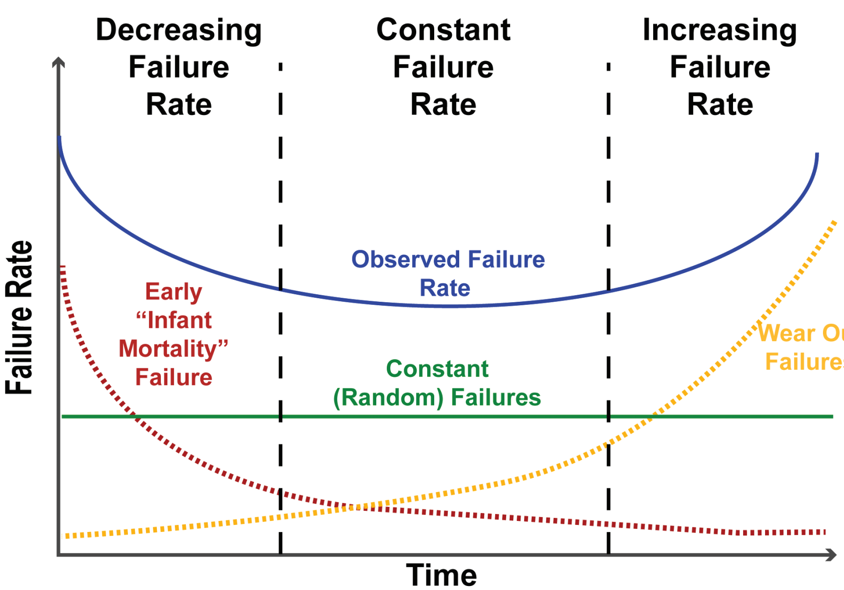



**Figure 8.3** Bathtub Curve used in reliability engineering [Arnold Vogt, 2016].

Methods for improving reliability can be divided into two families [Jantunen, 2016]:

- **Proactive methods:** they seek to improve reliability using techniques that allow gradual removal of both persistent and potential failures;
- **Reactive methods:** they seek quick and effective solutions to daily problems and to avoid repetition of major failures. Basically, it consists of "post-mortem" methods and its main exponent is RCA.

At this time, there are multiple maintenance techniques, methodologies and philosophies. The use of these methodologies is sector dependent and also differs between companies within the same sector. The main factors that drive the selection of a methodology are the risks and impact of the failures, the cost and implementation difficulties, and the competitive intensity within the sector. The most common tools, trends and methodologies are detailed below.

### 8.1.1 Tools

This section gets through the most used strategies and techniques applied for advanced maintenance operations.

#### 8.1.1.1 Total productive maintenance

Known for the great benefits obtained in manufacturing companies and bold success stories in Japan, TPM emphasizes teamwork and it leans on correct cleaning and lubrication for chronic failure removal. It involves a strong team culture and sense of belonging to employees. When this is not applicable, a cultural shift is required as it is strongly related to continuous quality improvement and zero-defects philosophies. Anyway, this is difficult to implement in process-focused companies due to the ambiguity between the concepts of quality and defects [Márquez et al., 2004].

When the roll-out of the methodology has been successful, there have been vast improvements in safety, reliability, availability and maintenance costs.

#### 8.1.1.2 Root-cause analysis

RCA is a very powerful technique that allows problem resolution with a short and mid-term view. It uses exhaustive research techniques with an intent to remove problem and failure root-causes. Its value is not only to avoid critical events but to eliminate chronic events that tend to consume maintenance resources. Gradual chronic and small problem removal require deeper analysis [Márquez et al., 2004].

#### 8.1.1.3 Reliability centered maintenance

RCM is a technique that appeared in the late 90s to respond to high maintenance (preventive) costs in aircrafts. It proved its validity within the aerospace's sector, not only lowering costs and maintenance activities but also improving reliability, availability and security. This makes it appealing to other industries such as military, oil & gas and utilities [Brisk Insights, 2016].

It is based on selecting maintenance only in the case that failure consequences so dictate. To do so, exhaustive studies have to be carried out for every function. RCM establishes priorities: safety and environment, production, repair costs. This has made this technique a very valuable tool in industries with high-security demands, generating excellent results.

#### 8.1.1.4 Improving operational reliability

*Improving Operational Reliability* gathers the best maintenance practices and operations with a business focus recognizing maintenance limitations to reach appropriate reliability levels [Márquez et al., 2004]. This technique focuses on different aspects of operational reliability (see Figure 8.4).

It divides the techniques in:

- Diagnosis: using short/mid-term reactive and long-term proactive opportunities;
- Control: RCM as proactive technique and RCA as reactive. Also, Improving Operational Reliability used for static equipments;

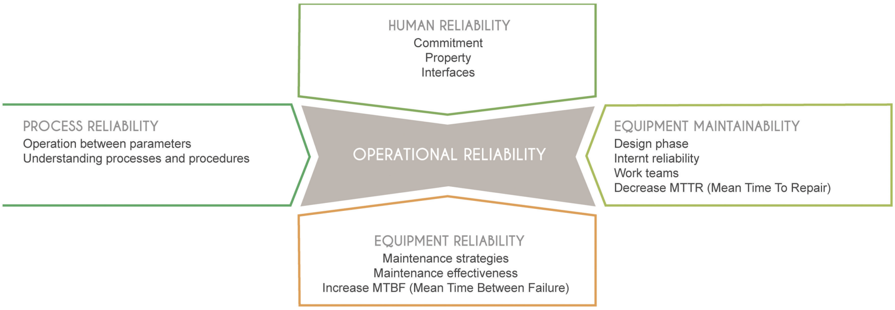



**Figure 8.4** Aspects of operational reliability.

- Optimization: using advanced statistical risk management tools for optimal maintenance intervals, downtimes, inspections, etc.

#### 8.1.1.5 Criticality analysis

This methodology allows establishing hierarchies or priorities of processes, systems, and equipment, creating a structure that makes decision making easier and effective. Efforts and resources are analyzed in key areas based on real data [4].

Once areas are identified it is much easier to design a strategy to make studies or projects that improve operational reliability, initiating applications to a group of processes or elements that form part of high criticality areas.

#### 8.1.1.6 Risk-based maintenance

This technique establishes inspection patterns for static equipment based on associated risks. It is a methodology for determining the most economical use of maintenance resources. This is done so that the maintenance effort across a facility is optimized to minimize any risk of a failure [Márquez et al., 2004].

A risk-based maintenance strategy is based on two main phases:

- Risk assessment;
- Maintenance planning based on the risk.

#### 8.1.1.7 Maintenance optimization models

These are mathematical models whose purpose is to discover a balance between costs and benefits, taking into account all type of restrictions.

The maintenance optimization models provide various results. First, they can be evaluated and used to compare different strategies regarding the characteristics of reliability and profitability. Second, the models can be monitored. Third, the models can determine how often to inspect or maintain the assets. Fourth, results of the evaluations of the models can be used for maintenance planning.

#### 8.1.1.8 Model-based condition monitoring

This tool involves the monitoring of one or more condition parameters in machinery (vibration, temperature etc.), in order to identify a significant change that is indicative of a developing fault.

The following list includes the main condition monitoring techniques applied in the industrial and transportation sectors:

- Vibration Analysis and diagnostics;
- Lubricant analysis;

- Acoustic emission (Airborne Ultrasound);
- Infrared thermography;
- Ultrasound testing (Material Thickness/Flaw Testing);
- Motor Condition Monitoring and Motor Current Signature Analysis.

The use of Condition Monitoring is becoming very common. It was originally used by NASA to monitor and detect errors in the development of spacecraft engines.

### 8.1.2 Trends

This section provides some background on a number of different strategies that are currently gaining interest in the field of maintenance.

#### 8.1.2.1 Servitization

Currently, traditional product-centric models are being transformed into customer-centric models where the focus shifts from creating the best product to the best solution for the customer. Product-based organizations focus their efforts on the development of products that they put on the market rather than the development of client-driven solutions. In the former model, companies sell and customers buy, whereas, in the latter, the company is focused on meeting customers' needs. There is also a symbiotic model where both, the vendor and the client collaborate in a solid relationship in order to succeed (Figure 8.5).

Variations on the product-driven model have been predominant in the manufacturing industry so far and services have historically been a small fraction of revenue (around 10–20%) for traditional manufacturing companies, although having greater gross margin compared to traditional goods' sales.

In order to survive and thrive in a globalized market, companies are being forced to develop intelligent maintenance solutions and move towards a balanced mix of product- and client-focused approaches. Hence, companies will benefit from high service gross margins, much less adjusted than the traditional product-focused ones (Figure 8.6).

Most companies recognize the urgency for moving their approach towards this new model, also known as Servitization, and thus are creating sophisticated platforms that leverage IT innovations such as cloud computing, machine learning, distributed databases, sensors, embedded solutions and so on, to create services that offer customized added value for the customer.

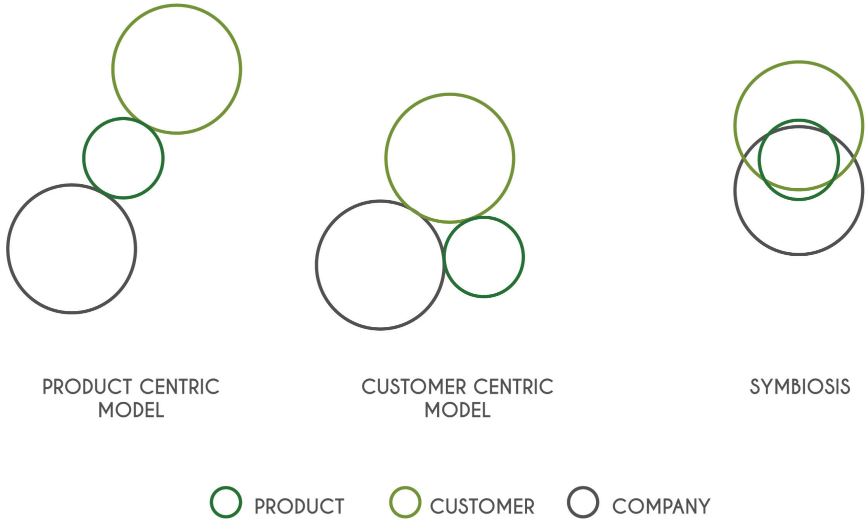



**Figure 8.5** Different models of collaboration between vender and client.


**Figure 8.6** Margin in product-driven model vs margin in service models.

#### 8.1.2.2 Degree of automation

The level of maturity of the maintenance platforms and the degree of automation (Figure 8.7) differ greatly among the studied organizations.

For example, global 500 company Siemens has launched in Q1 2016 its platform – MindSphere – for optimizing asset performance, energy and resource consumption, maintenance and related services. Siemens will integrate it with existing platforms of the entire value-chain. SAP launched "SAP Predictive Maintenance and Service, cloud edition" on November 2014; IBM is able to predict and prevent asset failures, detect quality issues and improve operational processes since 2012 with its platform. Large Enterprises such as Rolls Royce have been performing predictive maintenance related activities for a long time being for them IoT and cloud-based platforms an evolution, instead of revolution. Trumpf founded Axoom (2015, within the framework of a consortium), a digital platform that covers the complete machine tool


**Figure 8.7** Degree of platforms automation among organizations.

solution value-chain with the goal of shifting from being a machine vendor to a software vendor.

Current market solutions can be divided into **a) customized solutions** that cover the all maintenance services and **b) standardized mainstream platforms** [Arnold Vogt, 2016]. The current trend among large companies is to acquire the former due to the high level of customization and complexity that companies demand. Among SMEs, the standardized platforms are popular due to agile implementation efforts.

Vendors are trying to merge both solutions with the aim of providing customized vertical solutions (extensions) based on standardized platforms. New functional modules -verticals- are getting installed on top of horizontal core platforms and provide customized experiences to the user (Figure 8.8).

### 8.1.2.3 Top-down vs. bottom-up

Market leaders see Industry 4.0 as a Roadmap to build the ultimate CPS where smart products have all the information to be manufactured in every step of the value chain and the flexibility to adapt to changing conditions in an integrated production lifecycle, from product design to services (Figure 8.9). In short, market leaders are pursuing a strategic top-down approach.

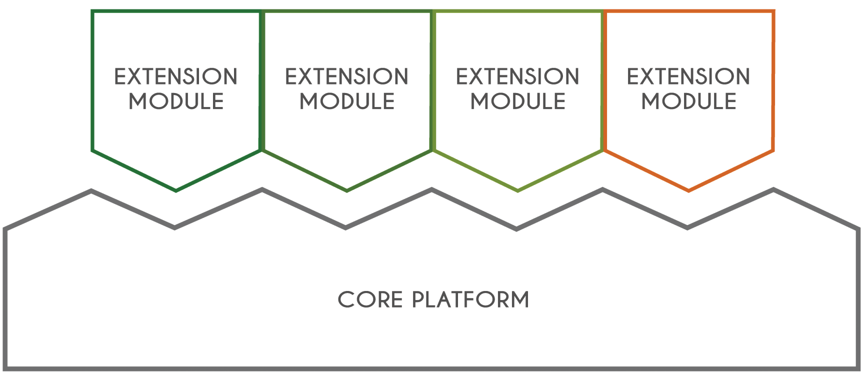



**Figure 8.8** Customized vertical where solutions based on standard platform.


**Figure 8.9** Top-down approach, where the product has all the information in every step of the value chain.

Meanwhile, some Large Enterprises and SMEs are building platforms bottom-up in a Lean strategy, with a more limited functional scope to digitalize a particular area. In maintenance, this scope usually covers:

- Monitorization, and smart data analytics;
- Customized reports, alerts and warnings;
- Consulting services.

#### 8.1.2.4 Smart products

Smart products are CPSs providing new features and functions based on connectivity. In industry 4.0 the smartification of the products and machinery is a key factor for the predictive maintenance. The information gathered from products and machines are translated into maintenance plans and products improvements (Figure 8.10).

#### 8.1.2.5 Machine learning

There are several software techniques and methods that uncover hidden patterns in large data-sets. ML in particular deals with algorithms that give computers the ability to learn based on empirical data.

ML makes software applications act without being explicitly programmed. ML has made possible the emergence of self-driving cars, effective medical diagnosis, chess champions (Deep Blue) and a deep inflection point due to AlphaGos win (Googles DeepMind). AlphaGo relies on several ML components, like deep neural networks and tree search.

Many companies are looking at using ML in their products. The manufacturing industry is not an exception, and it is currently developing algorithms to make data-driven predictions or decisions.

## 8.2 Shift to a Proactive Maintenance Business Landscape

The current technical development in industry regarding information handling and digitalization leads to new ways of producing goods. The industry demands flexible, safe, environmental friendly and available production

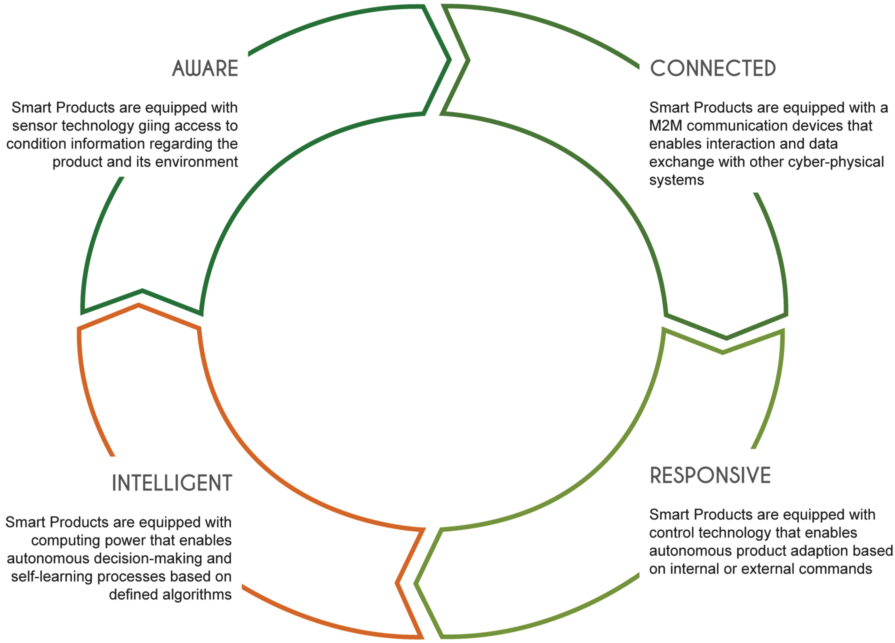



**Figure 8.10** Smart product as CPS providing new features and functions based on connectivity.

processes. At the same time, production processes become more automated, complex and dynamic. This approach, called Industry 4.0, focuses on delivering advanced technical solutions to manufacturing problems and supporting new industrial philosophies such as lean production, but in order to become successful these technical innovations in manufacturing must be connected with strategic business models.

In order to get an effective and successful business model, the characterization must be oriented in a dynamic market that demands flexible product-service model. The PMM business models analysed during the execution of the MANTIS project have this orientation.

Predictive/proactive maintenance solutions are common in processing industries like Oil & Gas, Wind, Utilities, and aerospace. These solutions allow efficient critical asset management based on condition monitoring using predetermined models.

Monitored data correspond to parameters such as vibration, lubrication, temperature, and strength, among others. For example, vibration analysis can be used to detect regular mechanical defects like lack of alignment, component erosion, and union weakening.

A normality model is established as an ideal standard, consisting of a specification of how an asset behaves under certain conditions, and therefore, a deviation of the "normality model" indicates asset deterioration. The model has to be able to offer early predictions and exact diagnosis. The model of normality is built based on several approaches:

- An empirical approach based on historical asset data;
- Engineering approach based on engineering principles that help describing how an asset should function under specific conditions;
- A combination of the empirical and the engineering approaches.

The design and implementation of a good model of normality require a precise asset's know-how in order to define failure patterns. A pivoting process readjusting parameters and KPIs helps to establish a robust normality model.

Manufacturing facilities also use PMM solutions to verify conditions of their most critical assets, although their degree of implementation is lower than in the processing industries. There are barriers that have to be overcome if PMM solutions are expected to be successful. They can be summarized as follows:

- Complex and extended asset mix. Depending of the type of industry, the critical chain focuses on few or huge amount of equipment;
- Capacity to function with changing conditions. The working conditions of assets are usually variable due to a high level of human interaction, a wide range of materials, multiple asset operations and changing processed end-products;
- Asset data availability. Many critical assets are not monitored and not even have data capture options so they cannot be substituted by smart assets in a short period of time;
- Confidence in PMM solutions. The high degree of skepticism regarding technologies capacity with respect to traditional maintenance methods.

Advanced predictive/proactive maintenance solutions are supported by technological innovations. The rise of Cloud Computing, distributed databases and the establishment of machine learning algorithms, among other technologies, are helping companies create new sophisticated maintenance solutions and allowing new business models to emerge.

Proactive and Monitoring Maintenance solutions analyse data from multiple sources (Physical assets, SCADA, PDM, PLM, ERP, etc.) and provide recommended actions based on smart analytics, using advanced statistical models such as classification, regression, associations, clustering and many more.

### 8.2.1 Key Success Factors

According to IBM [IBM, 2013], 83% of CIOs cited advanced analytics as the primary path to competitiveness enabling Asset Performance by a) improving quality and reducing failures and outages, b) optimizing services and support and c) optimizing operations, maintenance and product quality. As a title of example, Table 8.1 maps this path to competitiveness onto the predictive maintenance use case.

Companies need transformations to be competitive as they face unprecedented global challenges. Thus, new type of organizations are emerging and highly skilled workforces are joining multidisciplinary teams that work with tools that improve communication and remote work. Offices are also transforming into open spaces that encourage creativity, ideas exchange and places where different teams work together in order to create innovative products and services. Organizations create internal structures to satisfy demands of new generation of users who make heavy use of smart devices in their everyday lives.

To elaborate the mentioned products and services, and to attract talent from other sectors, manufacturing industries need to take into account a number of points that are developed in following subsections, namely: User Experience, Privacy, Scalability, Technical Debt, Skills, Organizational structure, Technology.

#### 8.2.1.1 User experience

UX encompasses all aspects of the end-user's interaction with the company's services and products. UX is a broad term and should not be confused with User Interface (UI).

UX is how a person feels when interacting with a product. These feelings include usability, accessibility, performance, design/aesthetics, utility, ergonomics, overall human interaction and marketing.

Companies with highly effective UX have increased their revenue and the business benefits can be summed up into three categories:

- Increased productivity: helping users to solve tasks faster and easier;
- Reduced costs: less training and support for the end-users;
- Increased sales: providing superior experience, and thus, market differentiation.

**Table 8.1** Predictive maintenance solutions to client and vendor [IBM, 2013]

| Key Metric | Business Benefit | How Advanced Analytics enables Value |
|---|---|---|
| **Maximize Revenue**<br>*Competitive Advantage* | • Products and services<br>• High availability<br>• Lower Start-up costs | • New products and services, Up Sell opportunities, Higher product quality<br>• Better asset utilization, more production cycles<br>• Fewer reworks, fewer installation repairs |
| **Cost Savings**<br>*Increased Reliability* | • Less Unplanned downtime<br>• Better productivity<br>• Better quality | • Fewer failures, faster problem identification, better process throughput<br>• Issues cost avoidance, faster root cause, higher equipment utilization<br>• Proactive monitoring, predictive performance, identification of factors likely to result in diminished quality |
| **O&M Costs**<br>*Increased Efficiency* | • Non-production costs<br>• Shorter maintenance<br>• Lower warranty costs | • Fewer failures, fewer emergencies, less need for excess MRO inventory<br>• Predictive maintenance, better planning<br>• Fewer Part failures, shorten issue resolution |
| **Customer Experience**<br>*Increased Satisfaction* | • Proactive management<br>• Individual experience<br>• Better collaboration | • Fewer surprises, proactive communication<br>• Focused communication, holistic view<br>• Information integrated across industries, better insight across silos |

#### 8.2.1.2 Privacy

With the emergence of Cloud-based software solutions that leverage underlying Big Data and Analytics power, concerns have risen regarding data privacy.

#### 8.2.1.3 Scalability

Successful product-market fit requires building platforms with strong scalability capacities. In addition, a correct balance between the different business models, full-service provider vs IoT platform vendor, as being successful in both is extremely difficult.

Platform based scalability can be achieved by strong IT infrastructures. Efforts that promote simplicity over complexity are preferable, as well as good usability design techniques.

#### 8.2.1.4 Technical debt

The surrounding infrastructure and platforms needed to support the system are vast and complex. A summary of the most relevant debts inherited from smart solutions follows:

- **CPS Complexity.** The implementation of intelligent CPS systems implies massive ongoing maintenance costs due to inherited-incidental and accidental-complexity;
- **Data Dependencies.** Data dependencies are not necessary causalities. Some data are unstable due to their changing behaviour over time and/or are underutilized/unneeded. This creates noise in the system so actions should be regularly put in place to identify and remove unnecessary data dependencies;
- **Glue Code.** Using general purpose libraries, third party open-source or proprietary packages, or cloud based solutions in the system results in glue code pattern;
- **Configuration Debt.** Systems allow to configure different options: features, data-mining techniques, data verification methods, etc. All this messiness makes configuration hard to modify correctly, hard to reason about and can lead to production issues;
- **Data Testing Debt.** Production issues are often caused by code bugs but also by data related issues, so some amount of data testing is critical to a robust and stable system;
- **Reproducibility Debt.** Re-running a process should return the same result but this is often not the case due to randomized algorithms, interactions with a changing physical world or similar causes. This adds complexity to the work of engineering teams;
- **Process Management Debt.** Real systems have various models running simultaneously. This raises many type of management problems that can cause production incidents;
- **Cultural Debt.** There is always a tension within a group of heterogeneous people (R&D, engineering, support,..) but it is mandatory to create a working culture that promotes reduction of complexity,

improvements in reproducibility, stability, and experience shows that strong multidisciplinary teams achieve better results.

#### 8.2.1.5 Skills

Smart Factories in general and PM in particular demand new labour skills. The identification of these future skill-sets and competencies is a key factor and can determine the success or failure of the project.

Strong emphasis on IT related skills is clear: UI/UX design, mathematics, data-science, Front and Back-End development, AI, Machine Learning, etc. In summary, a hybrid approach where engineers and researchers are working together on the same teams.

In these knowledge-based factories work-related training becomes critical for both, employees and customers.

#### 8.2.1.6 Organizational structure

A major factor of successful organizations will be the ability to create a "learning organization". The new digital paradigm demands continuous attitude to learn and share knowledge (Figure 8.11).

According to Capgemini consulting (Capgemini Consulting, 2014), "Agility" (Figure 8.12) in manufacturing can be defined as a company's ability to thrive in a competitive environment of continuous and unanticipated change. Customers will demand constant changes and technological innovations that have arisen need agile organizations in order to gain competitive advantage. In short, the only constant is change.

#### 8.2.1.7 Technology

Using software terminology, it is being said that anyone slower than you is over-engineering, while anyone faster is introducing the above mentioned technical debt. Balance is not easy and building robust, scalable, user-friendly and smart prediction systems is not a trivial task.

Pivotal digital technologies are greatly affecting manufacturers, so organizations must master these technology ecosystems. Below, some technologies that are transforming the industry.

##### *Cloud Computing*

Cloud-based platforms are on-demand infrastructures that provide shared processing resources and data to computers and other devices. Business leaders like Amazon and Microsoft offer -compelling- public clouds that

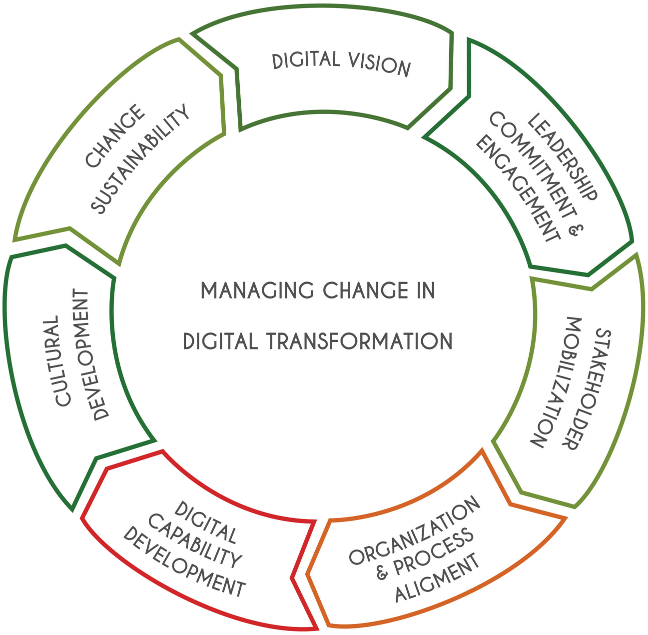



**Figure 8.11** Dimension of managing change in digital transformation.

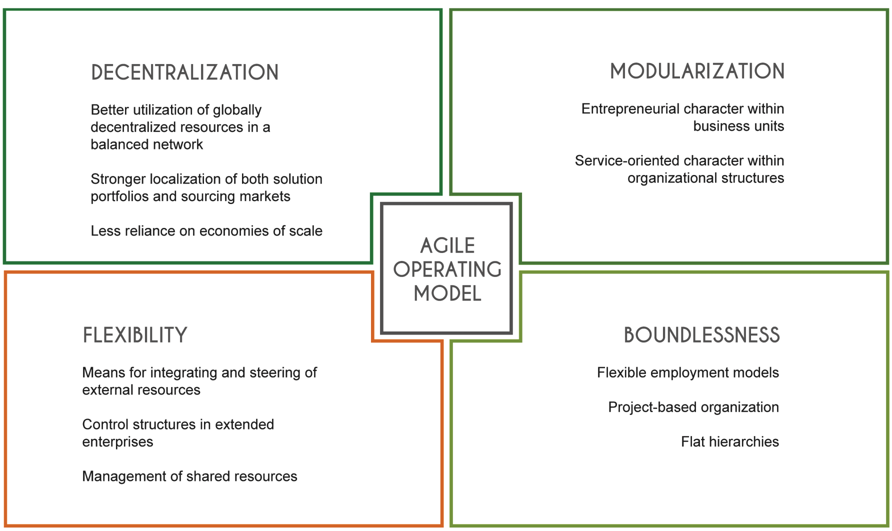



**Figure 8.12** Essential characteristics of an Agile operating model.

guarantee scalability and fast-and-easy deployments of applications, with less maintenance in a "pay-as-you-go" model.

There are also many software platforms (Open or Proprietary) for creating public or private clouds that can be run on a set of privately owned servers. As a title of example, one of the most growing Open Source solutions is Openstack.

### *Advanced analytics*

These are techniques and tools that simulate the future, predict possible outcomes and understand data with the help of powerful dashboards, charts and graphs.

This is a hot topic due to the emergence of data-mining and AI techniques that have got huge popularity in the software industry in recent years.

The basic idea is to transform raw data structured (easily entered, stored, queried and analyzed) or unstructured (refers to content without underlying predefined model that are difficult to understand, whose knowledge to represent, using traditional approaches) into meaningful and useful information, and this information into knowledge that helps in decision making. Currently, sophisticated software systems that are being developed have human-like "memory" so they can time travel to the past and simulate (and predict) the future.

User-friendly dashboards that display the mentioned analytics in any device (smartphone, tablet, desktop) and smart graphs and charts are also very popular for monitoring.

In summary, advanced analytics provide insights and actionable events to improve operational efficiencies, extend asset life and reduce costs.

### *Big data*

Massive data sets that traditional databases and software applications are unable to store, process and analyze. Gartner's Magic Quadrant for Operational Database Management Systems used to be dominated by SAP, Oracle, IBM and Microsoft with their traditional databases. In contrast, we now see Amazon's DynamoDB, MongoDB and many more NoSQL companies in that report.

Apache Spark is the Big Data platform of choice for many enterprises as it provides dramatically increased data processing speed compared to competitors, and currently is the largest Big Data open source project.

### IoT

IoT is basically connecting devices with the Internet and/or with each other.

Gartner predicted that by 2020 there were going to be over 26 billion connected devices [GARTNER, 2013]. The IoT is a giant network of connected "things": people-people, people-things, and things-things.

### Sensors

Devices that respond to physical stimuli (such as light, heat, pressure, magnetism, sound, etc.) and transmit a resulting impulse as a measurement or control. The corresponding output detect conditions that may affect the functioning of the machine and send the data to applications or clouds.

### Message broker

Responsible for taking input data or "messages" from physical or application layers, it performs some actions (transformations, aggregations, etc.) before sending the messages to destination (i.e.,: a database).

Thanks to message brokers, it is possible to integrate applications without enforcing a common interface and each application can also initiate interactions with other systems.

One very popular and heavily used open source library is Apache Kafka (Figure 8.13).

### Legacy systems

Existing technologies, applications and databases that companies have been using (and want to keep) need connecting (as data source, reporting, etc.) to new advanced solutions.

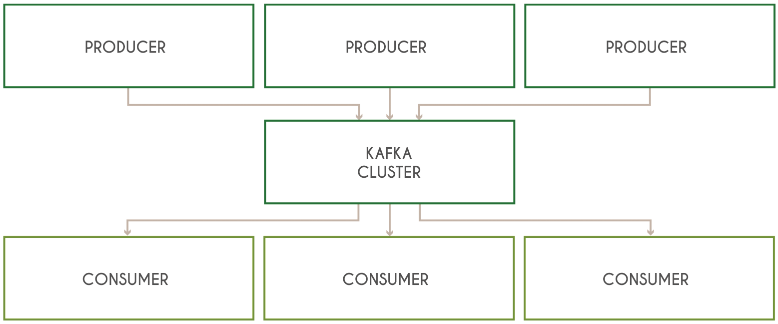



**Figure 8.13** Message broker Apache Kakfka, by LinkedIn.

The integrations with these legacy systems are important so great efforts have to be done to achieve smooth interoperability. Ideally integrations are done using web services (of REST type, for example) but due to old or proprietary technologies this is not always the case.

## 8.3 Proactive Maintenance Business Model

For PM to bring to the next level its contribution to profits, productivity, and quality, it must be recognized as an integral part of the business strategy, taking into account the clients necessities as the production targets where the whole business model is affected.

The main advantages of the PM business model are explained in the present chapter, based on the structure provided by the nine dimensions of the canvas (see Tables 8.2–8.4). As a general overview, four of the nine dimensions are analyzed: value proposition, key activities, customer relationship and revenue streams. The five missing dimensions depend on the internal specifications of the companies related to the use case. For example, in some of the analyzed use cases, they were Key Partners, Key Resources, Customer Segments, Marketing Channels, and Cost Structure.

The targeted proactive maintenance in the MANTIS project takes into account assets such as manufacturing, wind energy production, special purpose vehicles, health imaging systems, etc. The eleven use-cases considered in the MANTIS projects, which comprise the 9 use cases described in Chapter 7, can be divided and classified into three main categories:

- **Asset manufacturers:** machinery/equipment manufacturer, in many sectors being the same entities providing maintenance services and supplying spare parts;
- **Asset service providers:** entity in charge of building services upon production assets. Due to the transversality of data-based condition monitoring, often these entities cope with assets from very diverse vendors;
- **Asset end users:** exploiting assets capabilities. They have been traditionally the direct customers of the after-sales services. However, many of end users have adopted almost all preventive maintenance activities (even implementing some predictive features) of the equipment.

The competitive advantage of applying the PM process to each of the value chain segments are analyzed below.

**Table 8.2** Asset Manufacturer Canvas' key dimensions

| ASSET MANUFACTURER | | | |
|---|---|---|---|
| Value Proposition | Key Activities | Customer Relationships | Revenue Streams |
| *Asset design & production*<br>• Increase equipment lifespan<br>• Increase operational efficiency<br>• Improve quality<br>• Improve product lifecycle<br>Improve and optimization of product design<br>*Innovation*<br>• New product introduction<br>• R&D process optimization<br>*Supply chain & logistics*<br>• Delivery time optimization<br>*Customer experience*<br>• Improvement of accuracy of warranty modelling<br>• Production output customization | *Asset design & production*<br>• Asset reliability analysis<br>• Advanced HMI<br>*Innovation*<br>• Analyse remote product performance<br>*Supply chain & logistics*<br>• Stock management<br>*Accounting*<br>• Maintenance & warranty limits | *Asset design & production*<br>• Tap into customer base<br>• Machine virtualisation<br>*Innovation*<br>• Customer connected products<br>• Integrate real-time customer feedback<br>*Supply chain & logistics*<br>• Increased customer satisfaction<br>*Customer experience*<br>• Production/CRM integration<br>• Downtimes reduction<br>• Improved customization<br>*Accounting*<br>• Tap into customer base<br>• New payment models which transform capex into opex for asset end-users<br>• Financial services<br>• Retain customer<br>• Gain new customers | *Asset design & production*<br>• Idle time reduction<br>• Start-up time reduction<br>*Innovation*<br>• Accelerate time to market<br>*Supply chain & logistics*<br>• Workpiece traceability<br>*Accounting*<br>• Service business models<br>• Perpetuation of revenue streams instead of one-off asset sale for suppliers<br>• Customer's financial challenges overcome |

**Table 8.3** Asset Service Provider Canvas' key dimensions

| ASSET SERVICE PROVIDER | | | |
|---|---|---|---|
| Value Proposition | Key Activities | Customer Relationships | Revenue Streams |
| *Condition Monitoring*<br>• Downtime reduction<br>• Increase equipment lifespan<br>• Operational Efficiency Increase<br>• Quality Improvement<br>• Maintenance cost reduction (for end-user)<br>*Asset retrofitting*<br>• Increase equipment lifespan<br>*Other data-based services*<br>• Add-on services for primary products (e.g., consulting on best usage of products)<br>*Supply chain & logistics*<br>• Delivery time optimization Spare part traceability | *Condition Monitoring*<br>• Asset failure demand prediction<br>• Alarm triggering<br>• Advanced reports<br>• Remote monitoring<br>• Assets usage analysis<br>*Other data-based services*<br>• Advance training solutions<br>*Supply chain & logistics*<br>• Spare parts supply management<br>• Connected supply chain network<br>• Stock management<br>*Service operations*<br>• Service (& labour) planning & scheduling<br>• Business KPI definition and monitoring | *Asset retrofitting*<br>• Customised and systematic sales actions Customer inks consolidation<br>*Supply chain & logistics*<br>• Customer satisfaction degree increase<br>*Service operations*<br>• Tap into customer base | *Other data-based services*<br>• Additional revenue streams<br>• Potential sales argument for future offers<br>*Service operations*<br>• Maintenance operation cost reduction<br>*Accounting*<br>• Service business models<br>• Customer's financial challenges overcome |

**Table 8.4** Asset Service Provider Canvas' key dimensions

| ASSET SERVICE PROVIDER | | | |
|---|---|---|---|
| Value Proposition | Key Activities | Customer Relationships | Revenue Streams |
| *Asset utilization*<br>• Equipment lifespan increase<br>• Maintenance cost reduction<br>• Time to process orders reduction<br>• Production costs reduction<br>*Employee Productivity*<br>• Efficient training through collaborative solutions<br>*Sustainability*<br>• Energy consumption reduction<br>• Quality improvement<br>• Operational efficiency increase<br>• Rework & scrap reduction<br>*Supply Chain & Logistics*<br>• Accident reduction Stock reduction | *Asset utilization*<br>• Remote monitoring<br>• Connected factory<br>• Downtime management<br>*Employee Productivity*<br>• Training management<br>• Advanced HMI<br>*Sustainability*<br>• Energy management<br>• Quality control<br>*Supply Chain & Logistics*<br>• Factory safety management<br>• Connected supply chain | *Employee Productivity*<br>• Assistance systems<br>• Staffing readiness<br>• Worker mobility increase<br>*Supply Chain & Logistics*<br>• Product & process traceability | *Supply Chain & Logistics*<br>• Factory safety management<br>• Connected supply chain<br>• Product & process traceability<br>*Supply Chain & Logistics*<br>• Indirect monetization of insights from collected data |

### 8.3.1 Competitive Advantage for Asset Manufacturers

Providing advanced services upon asset maintenance has been identified by the VDMA (Mechanical Engineering Industry Association of Germany) as one of the most relevant strategic themes for European asset manufacturers growth, impacting on their digitization process and organizational structure. According to their report, companies expect to grow sales from digital business models from about 3% (2015) to 10% in 2020. Moreover, the development of advanced after sales services (such as predictive maintenance) has a huge growth potential: the previously named report states that it may impact on business profitability in a range from 1 to 4% (the average business profitability EBITDA margin is 6% within the European asset manufacturing industry). This is especially relevant for asset manufacturing SMEs, whose profitability barely reaches the average of 6%. Considering all factors, the implementation of PMM technologies will generate additional revenue sources (20% of revenue coming from services) as well as increase asset manufacturers business profitability (1 to 4% of EBITDA margin).

### 8.3.2 Competitive Advantage for Asset Service Providers

Even though this role has been traditionally played by asset manufacturers, within the transition towards a digitized European industry, ICT oriented companies have entered the market to answer the data management and analytics technological challenge. This kind of entities operates either in collaboration with the asset manufacturer or directly with the production asset end-user. According to the report Manufacturing Analytics Market, this market is estimated to grow from 3 billion (2016) to 8,1 billion by 2021, at a growth rate of 21,9%. Overcoming one of the biggest challenges, MANTIS will link the OT & IT worlds, by putting together production asset behaviour (mainly mechanical engineering knowledge) with failure data analysis knowledge, hence enabling data-driven maintenance business models. Tackling this problematic from a holistic point of view, MANTIS technologies will increase agility to respond to heterogeneous industrial shopfloors, enable cooperation with asset manufacturers to complement their value proposition, and provide better service to the production asset owners through adjacent predictive maintenance service.

### 8.3.3 Competitive Advantage for Asset End Users

As stated by the Manufacturer IT Applications Study conducted by Industry Week, manufacturers in average have to deal with up to 800 hours of downtime annually. Besides, 30% of the facilities experienced incidents within the first four months of 2013. The end users are willing to offer their facilities to test the innovative framework, which could give response to their specific needs. Besides, they will be able to replicate the experience in other production facilities. This will enhance MANTIS replication in a wide range of industries, coping with different production assets, MES, ERPs, CMMS, etc.

### 8.3.4 Value Chains

Depending on the business model archetype, it can be identified a series of value chains that can access or implement a PM business model on three stages of a company path: growth, digitization and organizational change, with reference to the framework defined by the business model archetypes designed by the VDMA in their [McKinsey&Company, and VDMA, 2016], and explained in Table 8.5.

### 8.3.5 Main Technological and Non-technological Barriers/Obstacles for the Implementation

Proactive maintenance implements safety in processes as the key element, needing a safety environment for every associated object and procedure involved. A function that is designed and developed to maintain safety is dependent on frequent maintenance in order to preserve its functionality and capability.

Barriers are often defined as an obstacle or function to prevent any form of risk to penetrate at an unwanted situation or process. The present situation in the industry indicates deviations in the common understanding and usage of barriers, and there are several areas of potential improvement [Moen, 2014].

For the Mantis project, several technological and non-technological barriers were identified, and are described below.

#### 8.3.5.1 Technological barriers

- **Trust in prognostics results.** Predicting failure of production assets (except isolated sectors, such as some defence applications) still remains a research field. This is mainly due to the fact that asset failure modes

**Table 8.5** Strategic Business Models Archetypes [McKinsey&Company, and VDMA, 2016]

| | | BUSINESS MODEL ARCHETYPES | | | | |
|---|---|---|---|---|---|---|
| | | Component Specialists | Asset Manufacturers | Equipment & Asset System Providers | Aftersales Providers | Software/System Providers |
| Strategic Themes | Growth | • Grow internationally through joint ventures and cooperation<br>• Explore adjacent business through horizontal integration<br>• Enter new price segments/several price segments (e.g., from premium to mid-price)<br>• Further understand and address needs of target customers | • Shift from products to services through vertical integration such as aftersales and offering software solutions, consulting services, etc.<br>• Further increase already strong level of interna-tionalization through intensified local value creation and shorter time to market | • Shift from products to services through vertical integration such as aftersales and offering software solutions, consulting services, etc.<br>• Offer customer-specific solutions at competitive cost through modulariza-tion/standardization to enable profitable growth<br>• Explore entry into new regional markets | • Broaden the scope of products and services offered through horizontal integration<br>• Further explore growth opportunities in new markets (e.g., Asia beyond China)<br>• Further address profitable mid-price segment | • Explore further growth opportunities in Europe<br>• Explore adjacent businesses, e.g., establish service provider business model towards third parties |
| | Digitization | • Use digitization in production to improve cost position and flexibility<br>• Strengthen | • Use digitization to improve production costs | • Assess new revenue sources and data-driven business models<br>• Offer consulting services on best | • Assess new revenue sources, e.g., increase aftersales share through predictive maintenance | • Assess new revenue sources, e.g., by offering consulting services on best usage of machines |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | customer interface through online store or configurator while investing in data security<br>• Use digitization for customization of products and services | • Use digitization to improve production costs | usage of machines<br>• Explore opportunities to reduce cost and to improve working capital | • Further develop differentiating offerings, e.g., establish platforms, to stay competitive vs. new entrants and grey market providers | • Invest in data security |
| | Organziational Change | • Build up a global organization across functions<br>• Continuously review strategic positioning(both business model and products)<br>• Increase operational agility to respond to economic cycles and increased customization | • Strengthen internationality of organization to further support growth abroad<br>• Build capabilities in business development and sales to identify and implement new business models | • Establish controlling mechanisms for customer cost-benefit analysis in engineering and sales<br>• Take cross-functional cooperation to next level<br>• Find right personnel with data analytics capabilities | • Increase strategic agility (e.g., portfolio definition) to respond to shifting profit pools<br>• Manage internal organizational complexity due to typically large size of organization and global footprint | • Increase agility to respond to new technologies and new growth trajectories<br>• Further globalize the organization (increase share of international employees, relocating functions abroad)<br>• Form cooperation with other machinery companies to leverage capabilities |

in industrial applications depend on a wide range of factors (often not monitored), and those assets (for obvious cost reasons) in most cases cannot be run to failure. That results in a lack of trust not only by asset end-users, but also by equipment and asset manufacturers;

- **Ability to support a mix of large-scale, heterogeneous assets.** A typical production plant employs multiple types of equipment identified as critical for production. Thus, predictive maintenance systems must be able to cope with a broad, complex and heterogeneous set of assets;
- **Interoperability with a wide range of production management systems (mes, erp, scada, etc.).** Each company has attained a different status regarding industrial digitization, which has a strong impact within predictive maintenance implementation (e.g., existence of a CMMS or not);
- **Ability to function under dynamic operating conditions.** Most of currently deployed manufacturing assets tend to operate with many product references, which imply highly dynamic operating conditions;
- **Relyability.** System robustness needs to be ensured with trial and error function. Model validation requires machines running to failure, which leads to high costs;
- **Connectivity.** The distributed sensors on machinery or other production assets need good wireless communication capabilities, which usually lack in industrial environments.

#### 8.3.5.2 Non-technological barriers

- **Conservative maintenance management culture.** As clear example of Industrial Internet of Things (IIoT) application, maintenance activities of manufacturing companies (identified as Operational Technology - OT organizations) are usually change and risk averse;
- **Need of training.** The implementation of predictive maintenance technologies, besides from the obvious technological challenges, directly impacts on workers (maintenance and other departments) daily tasks. Operators from different ages, abilities, experience levels, will provoke resistances to PM implementation, which can prove difficult to overcome;
- **Lack of resources.** Specialized resources, such as data scientists, are needed for the evaluation and implementation process. These resources are on high demand and in some cases cannot be found or are too expensive;

- **Legal.** In the case of providing a PM service, it is necessary to have access to the machine's data, which is owned by the customer.

## 8.4 From Business Model to Financial Projections

Many services have been proposed to transform product-oriented into service-oriented businesses in industrial sector as can be seen in [Neely, 2007] and [Baines et al., 2009]. Besides, to systematically design and communicate ideas for new service business models, the SBMC has been proposed by [Zolnowski, 2015]. Another approach is the framework for service and maintenance business model development in 4 levels and 6 dimensions by [Kans and Ingwald, 2016] and [Kans 2016]. One of the key characteristics of component-based business model representations, such as BMC or the SBMC, is their qualitative nature, which is very suitable for developing and characterizing the business proposal [Zott et al., 2010]. However, to justify internal funding of service business developed, an assessment of the financial projection is required.

The use of "services" implies a connotation inside of BMC that in future PMM Business Model is implicit. The most relevant change in industrial sector is to incorporate and use ICT in all of life-cycle of product in industrial sector. Thanks to ICT the term "service" can be used to address more concrete opportunities and options inside of BMC. In case of industry and manufacturing sector, it is possible to establish processes and options, which were surveyed by [Zolnowski et al., 2011]:

- Data collected in machines and products is analyzed for machine/product-related after-sales services, to increase internal knowledge, and improve performance/design or maintenance process;
- Remote services give manufacturer direct access to its machines. Furthermore, it permits repairs and adjustments without geographical constraints;
- Remote services help to improve internal processes via automation and parallelization in the whole life-cycle, to improve efficiency (cost reduction), and quality;
- Collection and analysis of customer data are automated and help to receive customer knowledge and perform new products and services taking into account better understanding of specific customers needs;
- Remote services and personalized offers facilitate relationship and send competitors to a situation of disadvantage;

- Remote services improve performance maintenance. Therefore, maintenance costs and time requirements decrease;
- Portfolio comprises entire chain, including plant layout, construction as general contractor, integration of inventory software, and after-sales services;
- After-sales services can be improved by leveraging remote services e.g., plant monitoring, operator support, and software management;
- Remote services allow for the development and provisioning of innovative services.

All of the options listed above, to a greater or lesser extent, are analyzed in the MANTIS PMM Business Model and the consequence in the maintenance process can be summarized as per BMC [Zolnowski et al., 2011].

Introducing a service business model directly affect economic evaluation and projection of a company, as seen in the Table 8.6. Moreover, in the characterization of SBMC it is necessary to not only take into account traditional cost structure in manufacturing but also consider the "service costs" to apply to the service model. As a consequence, investment on ICT such as specialized software and hardware are mandatory to allow for both savings through process improvements and revenues by additional services offered to customers. This leads to the first step to be taken in order to develop and quantify the potential impact on a business:

> To make the decision if to invest in a project, a Cost-Benefit-Analysis (CBA) has to be performed [Zolnowski et al., 2017; Boardman et al., 2017]

A CBA is an established tool for evaluating the economic benefit of an investment. As such, it can point out whether a SBMC could be implemented or by the contrary a different BMC definition is required. Although a service business model can be complex because of affected factors, systematic capture and analysis of CBA-related nuisances is a desirable objective. The next step for companies is to make the effort to evolve from a qualitative perspective of component-based business model representations to a quantitative information enriching and completing the business plan cycle.

There are different models to implement a CBA; [Anke and Krenge, 2016] describes a method called meta-model for "Smart Services", which was proposed for assessing data-driven services for connected products. The business case for smart services is associated with previous modelling processes. In their work, "smart services" are related to the process of digitalization and monitoring, leading to the result of a product/service with "connected smart connectivity".

**Table 8.6** Impact of remote service technology on service business models in manufacturing [Zolnowski et al., 2011]

| Key Partners | Key Activities<br>Key Resources | Value Proposition | Customer Relationships<br>Channels | Customer Segments |
|---|---|---|---|---|
| • Helps reducing the number of service orders placed with the partners of a company<br>• Requires the integration of new partners<br>• Collaboration with key partners allow the configuration of new advanced services | • Increases process automation of a company<br>• Improve the product development process<br>• New research activities<br>• Increase the quality of the products and services<br>• Requires IT integration between shop floor, office and life cycle<br>• Increase efficacy and performance indicators<br>• Increase the level of skills to advanced tasks | • Facilitates the introduction to the market<br>• Accumulates valuable information to offer better products and services<br>• Strengthen existing customer collaboration to have more knowledge and enable proactive service | • Helps to intensity the direct contact to the customer<br>• New relationships through software or IT | • Helps to increase satisfaction<br>• Increases the use of advanced technology in specific area<br>• Advanced Services can help to initiate new relationships to concrete possible customers |

| Cost Structure | Revenue Streams |
|---|---|
| • Reducemaintenance and services costs<br>• New costs related to advanced services | • Increase the revenues for new products and services<br>• New prices strategic for services<br>• New revenue streams due to new services make the company less dependent on the unpredictability of product sale and even out the cashflow. |

While the meta-model of [Anke and Krenge, 2016] is not directly related to a business model, it provides an interrelation between the service proposal and its financial evaluation. Figure 8.14 shows the business model diagram and financial diagram.

[de Jesus, 2012] explains how to proceed from BMCs to financial projection. Since in a company the earnings and revenues projections play a crucial role, the most relevant analysis aims to understand:

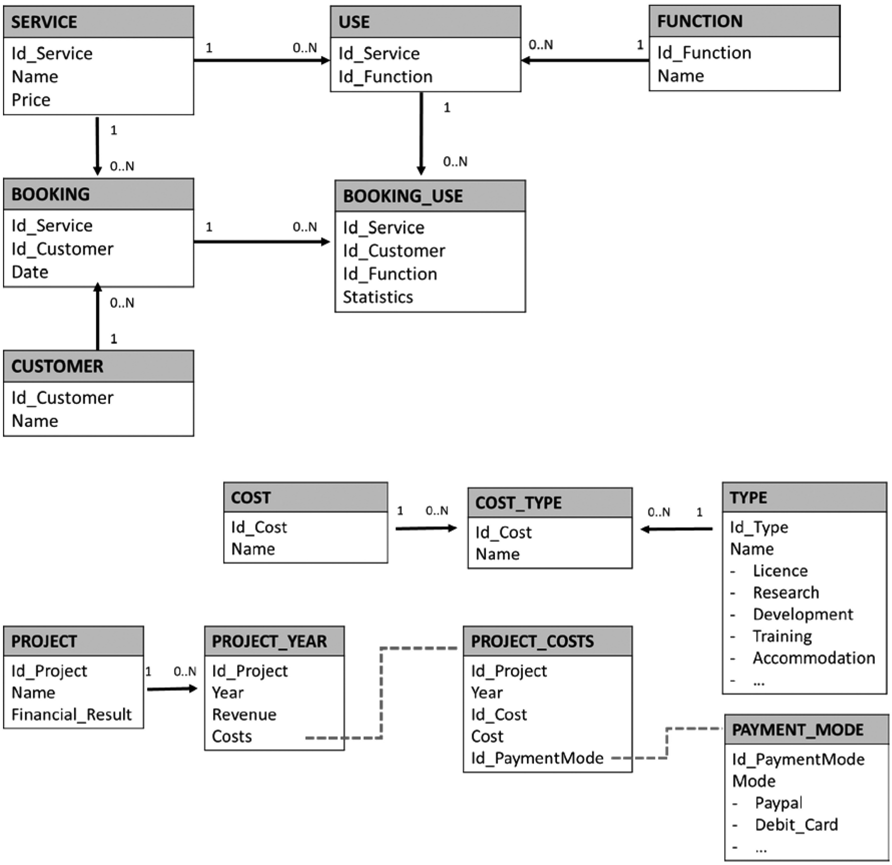



**Figure 8.14** Service and cost class diagram for the business case model [Anke and Krenge, 2016].

*"if the future company will be successful or not"*.

Hence, it proposes to merge the BMCs framework with P&L concepts. The P&L establishes in a specified period of time the results of the business performance and is able to specify the Cost Structure and Revenues Streams building blocks of the canvas in a more tangible way.

P&L is composed by the following items [de Jesus, 2012]:

- **Cost of sales:** expected direct cost of developing and performing the product and/or service that a company carries out;

- **Gross margin:** revenues less cost of sales. This is a key indicator to know the earnings of the company;
- **Operating expenses:** expenses the company needs to operate and manufacture;
- **Operating earnings/loss:** gross margin minus operating expenses. This indicator is closer to reality;
- **Income taxes:** taxes that a company needs to pay. This item depends on which country the company establishes their activity in.

The principal objective seeks that the revenue streams and the cost structure information are directly identified from the others seven blocks of the BMCs apart from specified cost and revenues blocks. In order to achieve it, [de Jesus, 2012] estimates the economic quantification of each element added in BMCs in terms of costs or revenues.

Finally, to complete the financial projections to the P&L analysis, the calculations of financial indicators could be provided as an overview of the business. The calculated indicators are the following ones [de Jesus, 2012]:

- **EBITDA:** gives an overall idea about the potential capacity of the business to generate cash. It is a measure of a company's operating performance;
- **Break even point:** it is the point from which the company begins to have positive operating results. Typical question to address this indicator is, how much needs to be sold in order to cover all fixed costs?;
- **Quantity critical point:** represents the minimum amount that the firm should sell in order to have positive results;
- **Security margin:** expresses the distance on the level of activity achieved by the company for the critical point;
- **Sales cost coefficient:** gives part of sales after that the variable cost is paid, which will be left to pay for fixed costs.

Aiming at supporting a better understanding by means of examples, in [de Jesus, 2012] there are 6 demonstrations of 6 different BMCs. For example, Portal dos Serviços is a startup that aims to be a trusty intermediary between health care service providers and private clients. Table 8.7 shows P&L in BMCs.

All of the parameters discussed above, namely EBITDA, break event point, quantity critical point, security margin and sales, cost coefficient, evolution and critical point, are shown in Figure 8.15:

**Table 8.7** *Portal de Serviços* cost Business Model [de Jesus, 2012]

| Key Partners | Key Activities<br>Key Resources | Value Proposition | Customer<br>Relationships<br>Channels | Customer<br>Segments |
|---|---|---|---|---|
| • Web providers<br>• Advertising companies 5.000 | • Platform Analysis and Design 40.000<br>• Specific and advanced profiles 20.000<br>• Logistics 30.000 | • Platform Development 70.000 | • Events 4.000<br>• Social Media 10.000<br>• Service center<br>• Press 2.000<br>• CRM 10.000 | • Private and liberal professional 3000 |

| Cost Structure | Revenue Streams |
|---|---|
| • Platform maintenance and development | • Product sells 300.000<br>• Services sels 80.000 |

Wurzbach [2000] performs a web based cost benefit analysis method for predictive maintenance through two principal points:

- Direct cost savings;
- Indirect cost savings.

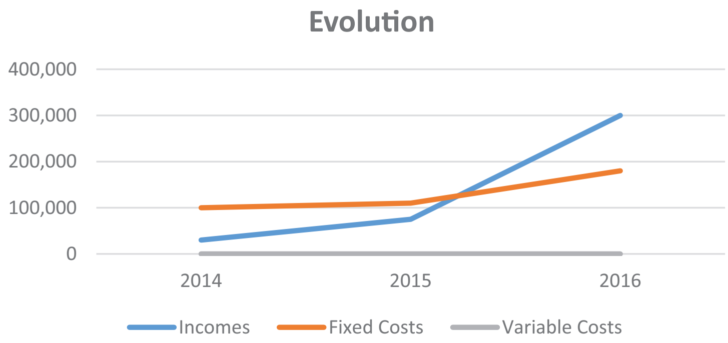
**Direct cost savings** are the principal group of costs to get benefit within a predictive maintenance program. These costs are recurring and usually established as annual direct cost reduction. Sometimes it can be new budgeted design and changes depending on information generated by the predictive maintenance program. Overall, these are one-time reductions but the savings can be relevant.

**Indirect costs savings** affect manufacturing and maintenance process but with ups and downs. Since productive lines and products can have different values of OEMs, indirect costs savings could be increased if failures are detected before development ends. Even in some cases with less differences between predicted and an unanticipated failure there could be significant savings in maintenance within the scheduling environment. Indeed, advanced maintenance program get the most benefit due to associated costs of unanticipated or "emergent" maintenance repair activities. Finally, advanced maintenance program provides overtime and parts procurement reductions as well as impact to facility operations as indirect cost savings.

Zolnowski et al. [2017] explains the principal items to take into account inside of:

- Cost;
- Revenues;
- Cost Savings from BMCs to financial projections.

| RESUME | |
|---|---|
| EBITDA | 9.000 |
| Gross Margin | -70.000 |
| Break even point | 100.000 |
| Quantity critical point | 9.000 units |




| | 2014 | 2015 | 2016 |
|---|---|---|---|
| Incomes | 30.000 | 75.000 | 300.000 |
| Fixed Costs | 100.000 | 110.000 | 180.000 |
| Variable Costs | 10 | 10 | 10 |
| Gross Margin | -70.010 | -35.010 | 119.990 |

**Figure 8.15** *Portal de Serviços* financial analysis [de Jesus, 2012].

In case of Costs, [Zolnowski et al., 2017] references a variety of costs that are directly related to the development and management of a Data-Driven Business Model (DDBM). The costs are associated with the implementation of data-as-a-service or analytics-as-a-service technology and as a consequence close to the development of future PMM Business Model, some of the possible costs are listed below:

- Monitoring and analysis of data system;
- Extension of sensors in the key activities and use and allocation of data and systems;
- Sensors, gadgets, data, and systems;
- Use of data and systems in the key resources.

A development phase is referenced, where the improvement or implementation of hardware infrastructure is an important cost factor as well as an industrial use case in MANTIS project. In manufacturing, customers have to implement:

- Hardware such as embedded system and sensors in their machines to collect data;
- Connectivity between customers machines and cloud servers.

Another factor to reference cost is Software. Software can be developed, purchased or leased in ad-hoc, on-demand or Software as a service way. Any case individualized and specified algorithms are needed for companies. Moreover, these algorithms need to be maintained as well as the infrastructure to give continuity of Business Model.

> Hence, [Zolnowski et al., 2017] highlights the items of infrastructure (sensor and systems), software (algorithms and processing, monitoring viewing data) and connectivity input as Costs.

In case of revenues, these can be enabled for any actor. From a company perspective, revenues can be generated as [Zolnowski et al., 2017] highlights:

- Sales of new services;
- Sales of data to third parties;
- Sales of machine because of more competitive product.

Some of the types of revenues analysed in the MANTIS use-cases highlight the sales of a new services and sales of the machines as the most representative returns.

While [Wurzbach, 2000] describes indirect costs, [Zolnowski et al., 2017] describes the importance of savings, especially for optimization of processes that lead to lower costs by the reduction of inventory (key resources) failures, personnel, and goods. These costs of operational processes are optimized for analysing data remotely, or to be replaced by automatized processes.

## 8.5 Economic Tool to Evaluate Current and Future PMM Business Model

Once it has been identified the most important characteristics from "Business Model" to "Financial Projections", the next step is to know the earnings, incomes or revenue streams and costs.

The current Business Model shows the actual business and results of a company performances during the last year with traditional activities in maintenance. On the other hand, future PMM Business Model shows the number of projections over the following five years with advanced services in maintenance.

At this point, the key question to ask is:

**Which are the items that you have to take into account in earnings, incomes or revenue streams and costs?**

[Burke, 2017; Pauceanu, 2016] or [Tanev et al., 2016] describes the principal elements to take into account related with earning, incomes or revenues streams and costs. In order to have a specific answer to the question above, the future business model must be considered as composed by two principal sections: **(1) The Business and (2) Financial Data.**

***In the Business*** section, it is necessary to develop a detailed plan that clarifies why the business is existing; the aims for the existence, client groups, products and services, and how it intends to develop and deliver those services and/or products. It acts as a road map for the organization and shows clearly the destination it seeks and the path to follow to get there.

This should also be accompanied by a description of the resources required to complete the Business journey.

Hence, you would describe and take into account the following items among others (Figure 8.16):

- Description of business;
- Product and services;
- Market analysis;
- Marketing plan;
- Operational plan:
    - Production;
    - Location and infrastructure;
    - Technology;
    - Human resources plan;
    - Spare parts/inventory/suppliers;
    - Competition.

In ***Financial Data*** section, projected financial statements with revenues and costs would be indicated. Moreover, cash flow, balance sheets etc. should be taken into account. The financial data section is built over the Business section, and it is a critical section to verify that the evolution of the business is viable, useful and maintainable over time.


**Figure 8.16** General components of business plan [Pauceanu, 2016].

Companies should present their own values in such a way that it shows that the business will grow during time and there is a successful strategy at the horizon where they can make profits. The rule of thumb is to be realistic and credible, represent the growth trajectory in an understandable and detailed manner, and to figures into components by target market segment or by sales channels and provide realistic estimates for revenue and sales.

### 8.5.1 Incomes Items

This section refers to elements pertaining to revenue streams, earnings and benefits. More concrete, companies should analyse market, product, defined services either current and future PMM Business Model or detailed model. Moreover, it considers how to reach the market through the marketing plan. All of these elements concur to determine the incomes. So, companies should know:

- **Unit sales:** this is done by determining the number of products sold yearly;
- **Price:** this is the price of products and services that are sold during a year. The first consideration in pricing a product is the value that it represents to the customer. If, on the checklist of features, the product is truly ahead of the competition, it is possible to command a premium price, but in that case, it is better to offer some extra functionalities as companies performed in future PMM Business Model.

In case of doubt, the market can set the price. Anyway, there are cases when the selling price does not exceed costs and expenses by the margin necessary to maintain your business robust. This leads to the utmost necessity to know competitors pricing policies.

To define the revenues, the type of company is a key aspect. **In case of industrial use-case** companies should indicate the incomes from product or service and also maintenance. At this point, companies should differentiate between traditional maintenance defined in current Business Models and advanced maintenance defined in future PMM Business Model (PMM BM).

- In the first case (current Business Models), companies will provide information of the last year and probably have some maintenance contract and call service to find out solutions from issues during the life of the product;
- In the second case (PMM BM), companies could offer some new services along with product. These services are probably related to data maintenance. As consequence, companies could have benefits from some applications that use this data such as desktop or mobile APP, dashboard HMI, Virtual or Augmented reality application, remote analysis etc. Companies can specify others if they consider. The values for the next five years are projections that could be accomplished or not at the end of the fifth year.

Thereby, companies have used a template in excel to provide economic information. Table 8.8 summarizes how to provide the information.

One more time, to provide this information industrial companies can rely on previous year profit and loss statement. Product represents the industrial asset that companies sell. In case of maintenance, table represents the principal items as contract or call service but they can specify others.

In an **industrial use case and future PMM Business Model** Table 8.9 indicates 5 year projections and new services maintenance.

**Table 8.8** Revenue streams template for current business model and industrial use case

| REVENUE STREAMS | LAST YEAR |
|---|---|
| PRODUCT | |
| MAINTENANCE | |
| Contract | |
| Call service | |
| Others (specify) | |
| TOTAL | |

**Table 8.9** Revenue stream projections template for future PMM Business Model and industrial use case

| REVENUE STREAMS PROJECTION | YEAR 1 | YEAR 2 | YEAR 3 | YEAR 4 | YEAR 5 |
|---|---|---|---|---|---|
| PRODUCT | | | | | |
| MAINTENANCE SERVICE | | | | | |
| Tele-analysis | | | | | |
| Mobile APP | | | | | |
| VR/AR application | | | | | |
| Dashboard HMI | | | | | |
| Others (specify) | | | | | |
| TOTAL | | | | | |

Maintenance service shows the new services that companies offer along with product. Table 8.9 enumerates some of possible items that companies could offer. Businesses need to plan the price and the number of clients to implant. Additionally, companies describe the principal keys of the current Business Model and future PMM Business Model, such as type or product, market, maintenance, KPIs, etc., in order to explains the future projections.

Overall, each year sales will be higher and incomes increase that would depend on an specific percentage to be decided depending on the market, commercial interests, commercial workers skills and added value of the product.

Regarding **technological providers**, a new Business Model will offer new software either ad-hoc or SaaS model. As a consequence, companies would estimate the revenues for 5 years in terms of consultancy, product license, customized etc. A unit price for each item should be set in order to concrete a technological revenue.

### 8.5.2 Cost Items

According to [Pauceanu, 2016] and [Featherstone, 2015] it is better to calculate costs before incomes because it is easier. Both of them agree about including **costs related to operational and marketing plan**.

The operational plan is related to design, and it controls the process of production. Companies have the responsibility of ensuring that operations and production are efficient and effective in terms of meeting customer requirements. Therefore, companies should include the cost of ***manpower*** to be engaged in production. This section includes the ***amortization*** of machines and ***spare parts*** to build the product as well as ***technology*** needs by manpower. Computers, laptops, mobiles, data center, servers, software licenses are examples about what companies can include.

Companies should also include ***Infrastructure*** expenses such as stationaries, office utilities, office rent, power and industrial warehouse among others. To complete all of the expenses, companies should not forget ***marketing, travel, and accommodation*** issues. Product or service could need its own marketing strategy. The purpose of advertising is to inform, persuade, and remind customers about your companys products.

Other issue is that some companies can decide in order not to invest in marketing. Travel and accommodation issues are costs to attribute when commercial workers are selling out of company office.

Eventually, companies should add ***maintenance*** cost. The principal common items could be:

- Travel expenses and accommodation;
- Maintenance workforce;
- Warranty repairs;
- Spare parts;
- Call centre.

Furthermore, companies should include **costs related to development advanced maintenance applications and associated services** in the incomes area. **Hardware items** such as IoT sensors to analyse maintenance information should also be added.

Costs projections for the future PMM Business Model tables includes five projection years and software and hardware costs associated to advanced maintenance.

Tables 8.10 to 8.12 allow to provide the description of costs for different kinds of companies focused on future PMM Business Models. The only two differences between the table of structure cost for current Business Model and the future PMM Business Model are the five year projections and hardware/software investments in maintenance.

In natural evolution of future PMM Business Model, the costs could be higher at least for the first or second year due to hardware and software investment. As a consequence for following years other costs associated in maintenance should decrease.

**Table 8.10** Structure cost template for technological provider business model projection

| REVENUE STREAMS PROJECTION | UNIT PRICE (Per Client/Asset) | YEAR 1 | YEAR 2 | YEAR 3 | YEAR 4 | YEAR 5 |
|---|---|---|---|---|---|---|
| Product license | | | | | | |
| Consultancy | | | | | | |
| Customization | | | | | | |
| Others(specify) | | | | | | |
| TOTAL | | | | | | |

**Table 8.11** Structure costs Template for current business model and industrial use case

| COST STRUCTURE | LAST YEAR |
|---|---|
| MANPOWER | |
| Factory workers | |
| Engineering and design | |
| Commercial workers | |
| TECHNOLOGY | |
| Hardware inside the product | |
| Software inside the product | |
| Data centre, server | |
| IT Support | |
| Computers, laptops, mobiles | |
| Software licensing | |
| TRAVEL EXPENSES AND ACCOMODATION | |
| To Sell | |
| INFRASTRUCTURE | |
| Industrial warehouse, business office | |
| Power, water, stationery, | |
| Administration | |
| MARKETING | |
| LOGISTICS | |
| Logistics and distribution | |
| AMORTIZATION | |
| PURCHASING | |
| Spare parts - products | |
| MAINTENANCE | |
| Travel expenses and accommodation | |
| Spare parts | |
| Warranty repairs | |
| Maintenance workers | |
| Call centre | |
| Others (specify) | |
| TOTAL | |

**Table 8.12** Structure costs template for future PMM Business Model and industrial use case

| COST STRUCTURE | YEAR 1 | YEAR 2 | YEAR 3 | YEAR 4 | YEAR 5 |
|---|---|---|---|---|---|
| MANPOWER | | | | | |
| Factory workers | | | | | |
| Engineering and design | | | | | |
| Commercial workers | | | | | |
| TECHNOLOGY | | | | | |
| Hardware | | | | | |
| Software | | | | | |
| Data centre, server | | | | | |
| IT Support | | | | | |
| Computers, laptops, mobiles | | | | | |
| Software licensing | | | | | |
| TRAVEL EXPENSES AND ACCOMODATION | | | | | |
| To sell | | | | | |
| INFRAESTRUCTURE | | | | | |
| Industrial warehouse, business office | | | | | |
| Power, water, stationery, | | | | | |
| Administration | | | | | |
| MARKETING | | | | | |
| LOGISTICS | | | | | |
| Logistics and distribution | | | | | |
| AMORTIZATION | | | | | |
| PURCHASING | | | | | |
| Spare parts - Products | | | | | |
| MAINTENANCE | | | | | |
| Software Development | | | | | |
| Sensor and hardware | | | | | |
| Warranty repairs | | | | | |
| Maintenance workers | | | | | |
| Spare Parts | | | | | |
| Travel expenses and accommodation | | | | | |
| Others (specify) | | | | | |
| TOTAL | | | | | |

This is because there is a product with additional maintenance services, especially predictive maintenance, which implies a reduction of overhead costs on it. There will probably be a decrease in repairs, spare parts, travels etc.

**Table 8.13** Structure costs template for technological provider use case

| COST STRUCTURE | YEAR 1 | YEAR 2 | YEAR 3 | YEAR 4 | YEAR 5 |
|---|---|---|---|---|---|
| Software development | | | | | |
| Hardware | | | | | |
| Platform maintenance | | | | | |
| Fixed costs | | | | | |
| Others(specify) | | | | | |
| TOTAL | | | | | |

Finally, a sustainable business should have less costs than incomes. Depending on the type of business this should be true somewhere during the five years projection.

**Cost Structure for technological provider use case** cannot take into account the same structure cost of the industrial provider. A typical software development company needs to have a new product:

- Manpower with programmig and consultancy knowledge;
- Platform maintenance costs;
- Hardware as sensor to obtain data from machines;
- Marketing expenses;
- Other costs.

Once companies filled the revenue streams and costs, either the current Business Model or the future PMM Business Model for an industrial use case or technological provider, it is time to address a detailed report. Next section describes the report schema to address.

### 8.5.3 Schema of Economic Evaluation and Projection Report

Regardless of the type of company, industrial or technological provider, the schema to address is:

- **Introduction**
  In this section each company will give a short description about their profile, the product and services they offer. Even, they could add some figures about annual turnover, market segmentation and objectives to address in MANTIS.
  This section it is useful to put some key information to help understand the sequential sections;

- **Value Proposition**
  Companies have the oportunity to explain in more details their use case associated with maintenance and the MANTIS project as well as the PMM value proposition for a 5 five years projection.
  The description of current and future value proposition incorporates new assets such as tecnology, services etc. which help to know deeply the business plan to address economic evaluation

- **Economic Evaluation and Projection**
  This is the most important and relevant section. Companies will show and describe numbers, figures, and some indicators associated with current Business Model and future PMM Business Model. Regarding current Business Model will be numbers only for one year, specially closed last year and the next 5 years in case of PMM Business Models.
  After filling the revenue streams and costs with tables in a spreadsheet described in the previous sections, companies will summarize economic information in Table 8.14.

Technological provider companies will show only 5 years projections because the aim is to offer new service through software as service and consultancy. Therefore, it is a new business that companies will describe in the BMCs tool and summarize the economic information in Table 8.15.

**Table 8.14** Economic evaluation and projection template for industrial use case

| | Current Business Model Year 0 | PMM BM Year 1 | PMM BM Year 2 | PMM BM Year 3 | PMM BM Year 4 | PMM BM Year 5 |
|---|---|---|---|---|---|---|
| REVENUES | | | | | | |
| Product | | | | | | |
| Maintenance | | | | | | |
| TOTAL REVENUE (1) | | | | | | |
| COSTS | | | | | | |
| Costs | | | | | | |
| Maintenance | | | | | | |
| TOTAL COSTS (2) | | | | | | |
| (1)-(2) | | | | | | |
| INDICATORS | | | | | | |
| % Maintenance incomes | | | | | | |
| % Maintenance costs | | | | | | |
| Others (specify) | | | | | | |

**Table 8.15** Economic evaluation and projection template for technological provider use case

| | BM Year 1 | BM Year 2 | BM Year 3 | BM Year 4 | BM Year 5 |
|---|---|---|---|---|---|
| **REVENUES** | | | | | |
| Product license | | | | | |
| Consultancy | | | | | |
| Others (specify) | | | | | |
| **TOTAL REVENUE (1)** | | | | | |
| **COSTS** | | | | | |
| Software/Hardware development | | | | | |
| Marketing and sales | | | | | |
| Others (specify) | | | | | |
| **TOTAL COSTS (2)** | | | | | |
| **PROFIT** (1)-(2) | | | | | |
| **ACC PROFIT** | | | | | |
| **INDICATORS** | | | | | |
| Nº of clients/licences | | | | | |
| Ratio revenues / costs | | | | | |
| Others (Specify) | | | | | |

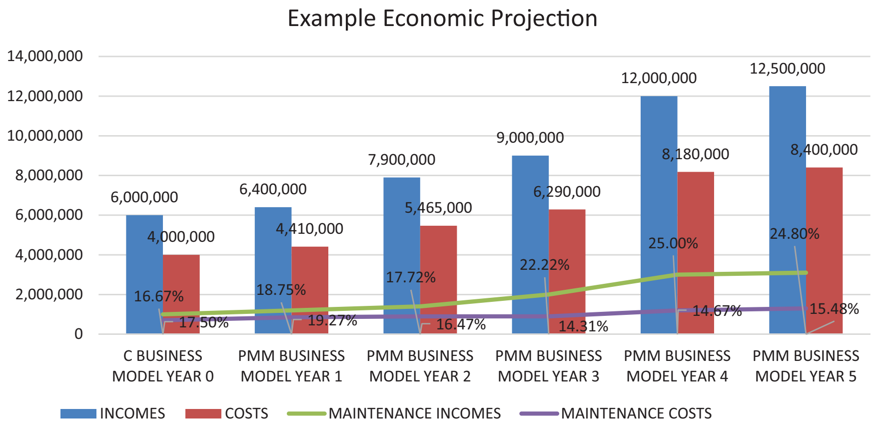



**Figure 8.17** Example economic evaluation projection.

Apart from the economic evaluation and description of most relevant figures and indicators (Table 8.14), the industrial use case companies will include a graphic to see the evolution in an easy and suitable format as can be seen in Figure 8.17.

## 8.6 Railways Use-Case Financial Business Model

Nowadays, the railway industry is in a position to exploit the opportunities associated to IIoT, enabling technologies under the paradigm of Industry 4.0.

According to [Roland Berger Study, 2017], railway sector supply, like other industries, sees four main levers driving the digital revolution as well as transforming existing business models: Interconnectivity [Fraga-Lamas et al., 2017], Digital Data [MARKETandMARKETS, 2016], Automation [Roland Berger Study, 2017] and Customer Interface.

The efforts in railway industry are concentrated on digitization of train control and maintenance, with a focus on CBM-based PM. The sector focuses in the definition of the root cause of failures, limit view on asset health, all of them leading to taking decisions based on facts instead of the experience and gut feeling of senior technical experts. Moreover, infrastructure development and maintenance costs represent a large part of the entire rail company budget. For all, the railway sector pretends to add new services, such as integrated security, asset management, and predictive maintenance to improve timely decision-making for issues like safety, railway assets, productivity, scheduling, and system capacity.

For carrying out a strategy associated with smart maintenance, key enablers comprise CBM, data integration and asset management with the use of advanced technology such as IoT, Sensors, Big Data Analytics, and advanced visualization services (Figure 8.18).

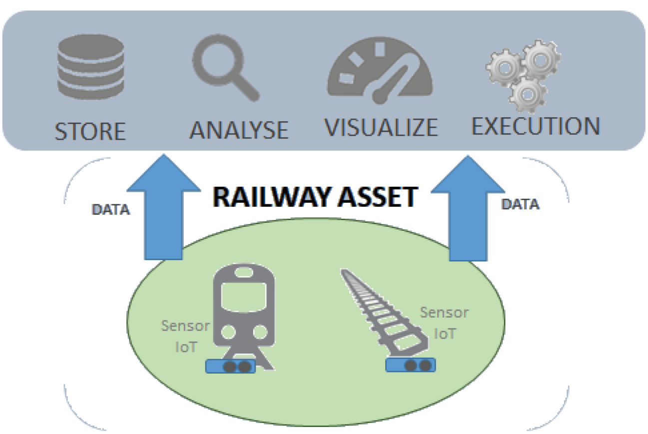



**Figure 8.18** Smart maintenance approach in Railway Sector.

PM models and approaches help to eliminate preventive and corrective interventions. The key intuition is suggesting the ideal time and measure for maintenance work using all the data. This way, diagnostic data are not only used as a control function, but also as a driver for maintenance activities shifting a paradigm and giving several advantages:

- Change from a reactive maintenance mode to a proactive one;
- Visibility on the health of the asset;
- Delivering support to intervention teams, helping them take the right decisions (grind, stuff, mill or change a rail);
- Reduce high costs by optimizing maintenance interventions;
- Determining the root cause of failures;
- Better usage of warranty recoveries;
- Financial forecasting;
- Create new services business models associated with new maintenance service approach.

According with [MARKETandMARKETS, 2016] study the global smart railway market is estimated to grow from $10.50 bn of year 2016 to $20.58 bn by 2021, at a CAGR of 14.4%. In addition, according to the International Transport Forum of the Organisation for Economic Co-operation and Development (OECD), by 2050, passenger mobility will increase by 200–300% and freight activity by as much as 150–250% with respect to 2010 [Fraga-Lamas et al., 2017]. These figures show the impact for every component of the value chain of the railway industry.

Due to investing significantly into railway digitalization, according to [Roland Berger Study, 2017] 89% of the rail industry executives expect changes of their business model. The incorporation of digital competitive strategies allow for new advanced services such as digital products, remote train maintenance, mobile app, etc. Therefore, the railway industry has to adapt to new market situation.

### 8.6.1 Financial Business Benefits Within a Specific Railway Maintenance Solution

In order to point out specific benefits in economic terms of Proactive Monitoring Maintenance, a railway use-case is used as an example. On first instance, the company has to define its short to long-term objectives. In the particular case of railways, the company wants to address a reliability test strategy, based on a mathematical and theoretical assumption, in order to validate the MTBF value (coming from predictive analysis) with a fixed confidence interval. The maintenance service cost could be optimized to save costs in work force with service intervals. On the other hand, exploitation results are mandatory to have new revenue streams in terms of advanced services.

To carry out these objectives the railway use-case had to change its actual maintenance business model. Generally, the typical maintenance service is reactive and the revenues are associated with maintenance contract. To implement the new strategy, the railway use-case implemented proactive and monitoring maintenance solutions as well as new advanced services. The requirements to implement were:

- Data acquisition: besides current diagnostic parameters (voltage, current, position at the end of manoeuvre and completion time of the last manoeuvre), the following key variables are monitored in addition to those mentioned above: distance between the point blades and thrust/load exerted by the point blades environmental condition (environmental temperature, humidity, temperature of the rail) and mechanical behaviour;
- Data processing: enabled by a failure preventive model, the system generates a set of alarms (sent to the maintenance staff) in order to avoid availability problems;
- Maintenance strategy optimization: based on data generated by the monitoring system, the system sends a set of recommendations to the maintenance responsible to facilitate maintenance operations and reduce down-times of the whole interlocking system.

The implementation of this strategy influences the revenue streams and costs. The principal revenues are:

- Increased total revenue regarding after sales services;
- Optimized maintenance in service efficiency;
- Saving costs in work force and maintenance service.

Regarding cost structure:

- Modular data acquisition system;
- Monitoring system: IT infrastructure costs;
- Maintenance staff costs;
- Monitoring centre maintenance costs (call and data centre).

Translating the revenues to economic terms, the traditional railway maintenance task involves 10% of the total costs, divided in the following items:

- Maintenance workers – 50%;
- Services – 14%;
- Spare parts – 13%;
- Capital asset replacement plan – 8%;
- Warranty repairs – 8%;
- Administration costs – 4%;
- Call center – 2%;
- Shipment – 1%.

Thus, the highest value concerns *labour costs*. Labour force covers the costs of specialized technicians in charge of carrying out maintenance operations to the customer premises in accordance with the maintenance contract.

The *services* item include costs of supporting maintenance interventions, in particular: the field testing operations, potential remote support and training of the technicians. The third item covers the costs of the spare parts and related procurement costs.

As data disclose, the most relevant cost is manpower followed by services and spare parts associated with maintenance.

Therefore, over the following 5 years in future Proactive Monitoring Maintenance Business Model the principal aim is to reduce above all the cost of manpower with the improvements performed with the special data acquisition, data processing and maintenance strategy optimization.

The Table 8.16 shows a theoretical saving in maintenance costs of 25% at year 5.

This projection could be achievable due to the decrease of the labour costs (see maintenance workers) that impact less and less on overall maintenance costs thanks to the new solution developed: avoidance of false calls for railway equipment and optimisation of maintenance through increased efficiency of related intervention times.

**Table 8.16** Economic Projection related to current and future PMM Business Model

| BUSINESS MODEL | Current Business Model | Proactive Monitoring Maintenance Business Model | | | | |
|---|---|---|---|---|---|---|
| YEAR | YEAR 0 | YEAR 1 | YEAR 2 | YEAR 3 | YEAR 4 | YEAR 5 |
| MAINTENANCE SERVICE REVENUES | N.A% | N.A% | N.A% | N.A% | N.A% | N.A% |
| MAINTENANCE COST | 10,0% | 10,0% | 9,5% | 9,0% | 8,0% | 7,5% |
| Maintenance Workers | 50% | 50% | 45% | 40% | 30% | 25% |
| Saving costs | 0% | 0% | 5% | 10% | 20% | 25% |

The maintenance cost reduction progression and the remarkable indicators are shown in Figure 8.19.

Hardware and software investment have been estimated around 2%, including industrialization costs of the prototype solution.

This may be considered a negligible value compared to the cost of maintenance workers (around 50% of the maintenance costs).

Therefore, taking into account the estimated investment costs and related financial commitment, the projection of labour costs may be reconsidered, reaching 25% at year 5.

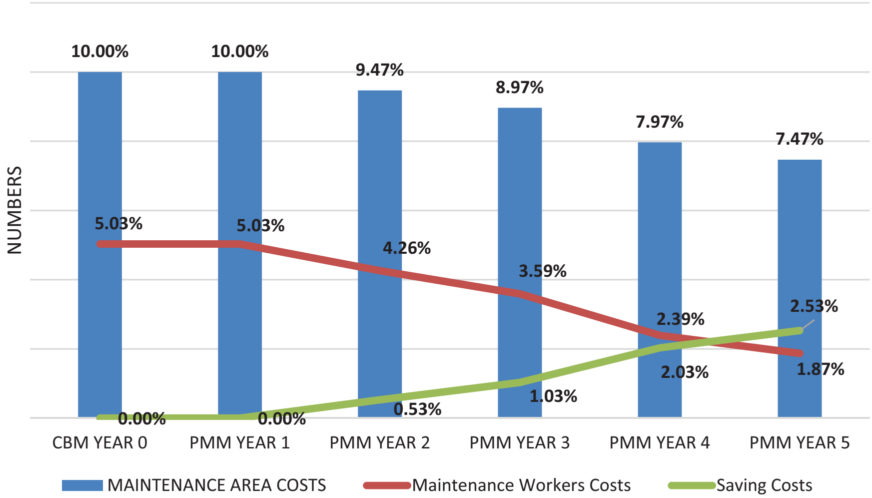



**Figure 8.19** Maintenance saving cost projection.

**Table 8.17** Advanced maintenance service program economic projection

| | PMM BM Year 1 | PMM BM Year 2 | PMM BM Year 3 | PMM BM Year 4 | PMM BM Year 5 |
|---|---|---|---|---|---|
| **Nº of Licenses** | 4 | 10 | 25 | 40 | 70 |
| **Revenues** | 40.000€ | 100.000€ | 250.000€ | 400.000€ | 700.000€ |
| **Development Costs** | 65.000€ | 40.000€ | 40.000€ | 45.000€ | 65.000€ |
| **Profit** | **-15.000€** | **60.000€** | **210.000€** | **395.000€** | **635.000€** |

Regarding new revenue streams, advanced services can be defined. New maintenance software is able to monitor the railway assets and know in real-time the status and perform possible correction actions. The services would have the numbers in Table 8.17 for 5 years, depending on client and market of each particular situation.

Railway industries as other industrial sectors have to adapt their business model to digitizing manufacturing and management processes, especially maintenance, to change from a reactive maintenance model to a proactive one.

This new strategy has some benefits such as visibility of health of assets, reducing costs by optimizing maintenance interventions, determining the root cause of failures, improving usage of warranty recoveries, etc.

The railway use case that was analyzed, has the objective to reduce the cost of maintenance manpower with the improvements performed, especially with regards to data acquisition, data processing and maintenance strategy optimization, under the rationale that it is the most important cost in maintenance (50%), with the next two items being maintenance services and spare parts, with 14% and 13% respectively. The 5 year projection considers a reduction of 25% costs in manpower.

Once the reduction of maintenance costs is achieved, in case of revenue streams, the objective would be to offer advanced services such as industrial asset monitoring to know in real-time the status of them and to perform possible corrections before downtime assets. The 5 year projections would include 70 assets to monitor with a profit of more than 600.000  by the end of year 5.

## 8.7 Conclusions

Ever since asset failures have caused downtimes and extra costs, accidents or inefficiencies, businesses have supplied material and human resources to minimize their impact and avoid their re-occurrence. Current approaches try to preserve function and operability, optimize performance and increase asset lifespan with optimal investments. The current technical development in industry regarding information handling and digitalization leads to new ways of producing goods. The industry demands flexible, safe, environmental friendly and available production processes.

PMM in the industrial sector is key to improve competitiveness, productivity, reduction of downtime machine, interventions for remote machines and travels among others. Proactive maintenance solutions are common in processing industries like Oil and Gas, Wind, Utilities, and aerospace. Across the new PMM paradigm, industrial companies and technological providers can offer new services associated with smart products. With aims to establish proactive monitoring and maintenance, companies should address a new strategy based on servitization and service business model adding new technology and services related to industrial internet of thing.

The new PMM strategy should be analysed through 9 blocks related to the well-known BMCs as well as economic evaluations in order to project the future benefits of the business model. Thus, **the value proposition** with the introduction of integrated IT solution to monitor industrial assets with some different characteristics depending on the sector. **Customer segments, relationships and channels** are the business models blocks are the most relevants to reinforce and relate the companies activities with the end-user for sharing asset data and new revenue streams. **Key activities, resources and partners** blocks help the development of the principal IT-OT system with predictive advanced algorithms, sensors, cloud system, middleware or research, allowing future competitive advantages. Finally, **cost structure and revenue streams** blocks to recognise the traditional and new type of payment as software ad-hoc or as a service or for asset availability, among other features.

Throughout the execution of the MANTIS project, current and future PMM Business Models Canvases were analysed by industrial partners in production asset maintenance, vehicle management, energy production and health equipment maintenance. In addition, economic evaluations and projections have also been analysed.

In the transition from traditional to PMM business models, a financial tool is applied in MANTIS project. The principal items to take into account on behalf of the financial tool are **revenue streams, costs and cost savings**. Each item impacts on a segment of the company's strategy, referring, for example, revenue streams to more competitive product sales, maintenance contract sales, consultancy or new maintenance software services. On the other hand, the financial tool should reflect the costs and investments, such as specialized manpower, new technologies, new infrastructure, new marketing strategies, even amortizations, travel expenses and logistics. All the maintenance changes on the business model should translate to a reduction of operational costs and incremental revenues.

Economic evaluation and projection was developed in the MANTIS project, resulting in economic data from last year and 5 year projections comparing current and future PMM Business Models for industrial business cases. For technological providers, new business model with advanced maintenance software as value proposition and 5 years projections were analysed.

The present chapter also described the **railway use-case for traditional to PMM business model**. Its main objective is to reduce the cost of maintenance manpower by means of improvements such as implementing tools as data acquisition, data processing and maintenance strategy optimization. As it was seen, maintenance cost is the most important one, with an impact of around 50%, followed by maintenance services and spare parts with 14% and 13% respectively. With the incorporation of new PMM strategy, in the 5-year projection the railway use-case would have a reduction of 25% costs in manpower. Other use-cases analyzed within the MANTIS project, achieved an impact between 15% to 25% on machine downtime, warranty repairs, intervention costs, manpower, among others.

Once the reduction of maintenance costs is achieved, in case of revenue streams, the objective would be to offer advanced services such as industrial asset monitoring to know in real-time the status of them and to perform possible corrections before downtime assets. The railway use-case, during the 5 year projection, would include 70 assets to monitor with a profit of more than 600.000  by the end of year 5. Due to techniques such as the servization of maintenance, the railway use-case, as well as others analyzed in MANTIS project, would imply an increase of income between 10% to 20 % .

In conclusion, PMM is key to improve maintenance processes applied in industrial companies, which can be either production asset maintenance, vehicle management, energy production or health equipment companies. New service business models should carry out monitoring industrial asset with sensors and predictive technology. As a consequence, new smart products with advanced services could be offered to achieve the impact to reduce around 25% in maintenance costs and increase 20% of revenue streams.

## References

Anke, J., and Krenge, J. (2016). Prototyp eines Tools zur Abschtzung der Wirtschaftlichkeit von Smart Services fr vernetzte Produkte.

Arnold Vogt (2016). Industrie 4.0 / IoT Vendor Benchmark 2017.

Baines, T.S., Lightfoot, H.W., Benedettini, O., and Kay, J.M. (2009). The servitization of manufacturing: A review of literature and reflection on future challenges. *J. Manuf. Technol. Manag.* 20, 547–567.

Boardman, A.E., Greenberg, D.H., Vining, A.R., and Weimer, D.L. (2017). Cost-benefit analysis: concepts and practice (Cambridge University Press).

Brisk Insights (2016). Operational Predictive Maintenance Market By Component (Solutions, Services), By Deployement Type (Cloud Deployement, By On Premises Deployement), By Application (Automotive, Energy And Utilities, Helathcare, Manufacturing, Government & Defense, Transport And Logistics), Industry Size, Growth, Share And Forecast To 2022.

Burke, P.Y. (2017). 74 – Business Plan. In Technical Career Survival Handbook, (Academic Press), pp. 185–186.

Capgemini Consulting (2014). Industry 4.0 – The Capgemini Consulting View.

Cristián M. Lincovil B, and G. Ivonne Gutiérrez M (2006). OPTIMIZACIN ECONÓMICA DE LA DISPONIBILIDAD.

Featherstone, S. (2015). 1 – Creating a business plan. In A Complete Course in Canning and Related Processes (Fourteenth Edition), (Woodhead Publishing), pp. 3–20.

Fraga-Lamas, P., Fernández-Caramés, T. M., & Castedo, L. (2017). Towards the internet of smart trains: a review on industrial IoT-connected railways. Sensors, 17(6), 1457.

GARTNER (2013). Forecast: The Internet of Things, Worldwide.

IBM (2013). Improving Operational and Financial Results through Predictive Maintenance.

Jantunen, E. (2016). Appendix 21: Existing business models related to proactive Monitoring and maintenance (PMM).

de Jesus, D.M.F. (2012). Financial Projection Based on Business Model Canvas.Kans, M. (2016). Service Management 4.0 and its applicability in the Swedish railway industry.

Kans, M., and Ingwald, A. (2016). Business Model Development towards Service Management 4.0. Procedia CIRP 47, 489–494.

MARKETandMARKETS (2016). Smart Railways Market by Solution (Passenger Information, Freight Information, Rail Communication, Advanced Security Monitoring, Rail Analytics), Component, Service (Professional, Managed), and Region - Global Forecast to 2021

Márquez, A.C., de León, P.M., and Herguedas, A.S. (2004). Ingeniería de mantenimiento: técnicas y métodos de aplicacin a la fase operativa de los equipos (Aenor).

McKinsey (2015). *The Internet of Things: Mapping the Value Beyond the Hype.*

McKinsey & Company, and VDMA (2016). How to succeed: Strategic options for European machinery.

Moen, E.F. (2014). Maintenance and barriers: Principles for barrier management in the petroleum industry will be more and more important and It is fundamental to understand the maintenance function in the barrier management. Institutt for produksjons-og kvalitetsteknikk.

Neely, A. (2007). The servitization of manufacturing: an analysis of global trends. In 14th European Operations Management Association Conference, (Turkey Ankara), pp. 1–10.

Pauceanu, A.M. (2016). Chapter 4 – Business Plan. In Entrepreneurship in the Gulf Cooperation Council, (Academic Press), pp. 79–118.

Tanev, S., Rasmussen, E.S., and Hansen, K.R. (2016). 2 – Business plan basics for engineers. In Start-Up Creation, (Woodhead Publishing), pp. 21–37.

Roland Berger Study (2017). Rail supply digitization

Wurzbach, R. N. (2000). A web-based cost benefit analysis method for predictive maintenance.

Zolnowski, A. (2015). Analysis and Design of Service Business Models.

Zolnowski, A., Schmitt, A.K., and Bhmann, T. (2011). Understanding the impact of remote service technology on service business models in manufacturing: From improving after-sales services to building service ecosystems. (ECIS), p.

Zolnowski, A., Anke, J., and Gudat, J. (2017). Towards a Cost-Benefit-Analysis of Data-Driven Business Models.

Zott, C., Amit, R., Massa, L., and others (2010). The business model: Theoretical roots, recent developments, and future research. IESE Bus. Sch.-Univ. Navar. 1–43.