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The Feasibility and Potential of Performance-Based Contracting in Heavy Machinery Industry

Examiners: Adjunct Professor Kalle Elfvengren
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PREFACE

Many days were spent feeling like this thesis work would never end. But it did. Was it enjoyable? Not really. Would I want to do another thesis? No, thanks. Am I happy I did it? Yes. I learned a lot in the process of writing and researching, but the biggest lesson I learned was that, more often than I thought, no-one has the answers. It is up to the person responsible of the outcome to make the best possible decision based on as much information as can be gathered within the limited time and trust the decision.

Thank you,

Sami Harju-Villamo

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Hakusanat: Ennakoiva huolto, toimintaperusteinen laskutus, esineiden internet, huollon liiketoimintamalli, PBC, teollinen huolto, laitteen toimintavarmuus

Tämä diplomityö tutkii huollon ja huoltoliiketoiminnan roolia teollisuudessa ja pyrkii tuomaan ymmärrystä ja selkeyttä vaihtoehtoiselle tavalle tehdä huoltoliiketoimintaa raskaan kaluston kanssa. Nykyaikainen holistinen näkemys teollisesta huollosta hyödyntää muun muassa sensoreita, etäyhteyttä, ennustavia algoritmeja ja ennakoivaa huoltoa, jotta laitteen kunto saadaan pidettyä hyvänä sen koko käyttöiänaikana. Tämä tehdään, jotta voitaisiin välttyä kalliilta, aikaa vieviltä ja mahdollisilta vaaratilanteilta, jossa laitteen toiminta pettää. Tuotantolaitokset ja tehtaat kilpailevat jatkuvasti nopeammista tuotanto- ja läpikulkunopeuksista. Materiaalien kulku ja valmistusajat voivat olla selkeitä kilpailuetuja yrityksille. Ongelma, jota edes moderni huollon näkemys ei ole ratkaissut, on asiakkaan ja toimittavat eriävät intressit. Tuotteen tai palvelun toimittaja ei suoraan hyödy asiakkaalle toimittamastaan lisäarvosta. Kiinteähintaiset sopimukset tuovat vakiotuottoa riippumatta asiakkaan tuotteesta saamasta arvosta tai sen muutoksista. Tämän diplomityön keskeisin tutkimuskohde, eli PBC, (Performance-Based Contract) on lähiaikoina eri aloilla suosiota saanut liiketoimintamalli, jossa asiakkaan laskutus perustuu suoraan toimitetun tuotteen tai palvelun suoritukseen, eli asiakkaan saamaan lisäarvoon. Työ tutkii, miten PBC:n avulla voidaan sitoa asiakkaan ja toimittajan intressit myydyn tuotteen toimintaan, ja asettamalla vastuun toimittajan hartioille. PBC siirtää laiteinvestointiin liittyviä riskejä tasapainoisemmin asiakkaan ja toimittajan välille, sekä tuo monia organisaatiollisia, käytännöllisiä sekä taloudellisia etuja. Toimintaperusteisilla sopimuksilla on korkea potentiaali yritysten liiketoiminta- ja innovaatiopotentiaalin kasvuun. Lisäksi asiakkaan on mahdollista saavuttaa matalammat kustannukset laitteen eliniän ajalta, saavuttaen samalla korkeamman toiminta-asteen, kapasiteetin ja laitteen luotettavuuden. Onnistunut toimintaperusteinen liiketoimintamalli vaatii hyvän ymmärryksen mallin riskeistä, perusoletuksista, toimintaperiaatteesta ja hallinnasta niin toimittajan kuin asiakkaan osalta.

ABSTRACT

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This thesis studies the role of maintenance in industrial companies and attempts to shed light on an alternative way for maintenance business. The modern holistic view of industrial maintenance uses sensors, remote connectivity and monitoring, predictive algorithms, and preventive maintenance to maintain assets at an operational state. All this is done to minimize the amount of asset failures that could lead to costly, time-consuming and dangerous situations. In the modern and hectic world today's industrial companies operate in, performance has become a critical competitive factor. The lead times in manufacturing and material flow in supply chains can be what sets a company apart from its competitors. The issue even with the modern approach to maintenance, is that it doesn't encourage the asset and maintenance supplier to improve the value the client gets out of sold assets. After an asset sale, a maintenance contract is made, and the asset will be serviced according to the contract. This means the supplier's income is constant, no matter how well its asset and service perform. The focus of this thesis; performance-based contracting (PBC) is a different business model that ties client's payments to the performance of a product or service. This thesis shows how PBC works by making both parties interested in an asset's performance, and making the performance the responsibility of the supplier, as the supplier has the most related expertise. PBC transfers a lot of the risk involved in industrial asset investments from the client to the supplier, and brings many organizational, financial and practical benefits to both parties. PBC has a high potential for the supplier's business and innovation potential while reducing the client's costs over an asset's lifetime and increasing the asset's reliability and performance. The successful implementation of PBC in the heavy machinery industry requires good understanding of the principles behind why PBC works and how it should be managed by both the supplier and the client.

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1. INTRODUCTION

Conventional contracts pose a great risk exposure to the owners of industrial heavy machinery assets. These assets are often located in mission-critical environments, where downtime can mean significant losses in production quality and quantity, as well as safety hazards. Traditionally, contract fees are based on the estimated amount of resources (i.e. staff, hours, materials) used. Additionally, traditional contracts work in a way that the involved parties might have completely different incentives; the client benefits from high asset performance and supplier benefits from low costs. Traditional contracts can also significantly hamper innovation capabilities by restricting any changes in ways of working and processes.

Performance-based contracting, or PBC, is a modern contract model, that attempts to combine the interests of both the supplier and the client by linking payment to the performance of an asset. This thesis studies the feasibility of PBC in the heavy machinery industry through literature review, interviews and case examples. Then, this thesis will look at the most common pitfalls and critical factors of a successful PBC in heavy machinery industry.

1.1 Research Objective

The objective of this master's thesis is to research the potential of performance-based contracting (PBC) in a service-heavy, heavy machinery manufacturing industry, specifically in industrial equipment. The reason behind choosing service heavy industries is the fact that one of the main factors for choosing performance-based contracting is the transfer of risks related to owning, such as asset availability (down-time vs. up-time) and maintenance costs, from the buyer to the supplier.

A challenge many companies face is in identifying the best contract or business models for each customer segment and product. I use the existing theories to describe and analyze the barriers, challenges, opportunities and enablers for implementing the PBC business model

in industries with different products. I will also analyze the possibilities brought by combining PBC and similar business models with the cross-device communication and remote access to supplied devices made possible by the Industrial Internet of Things.

After a comprehensive examination and analysis of the current theories, I will move on to analyze the possibilities brought by combining PBC and similar business models with the remote access to supplied machinery made possible by the Industrial Internet of Things and increased connectivity. All this will be applied to the heavy machinery manufacturing industry in an attempt to identify how PBC could benefit the heavy machinery maintenance business. I will include unstructured interviews of management-level employees in a heavy machinery industry company. Many interviewees requested anonymity, and so the interviews will remain completely anonymous.

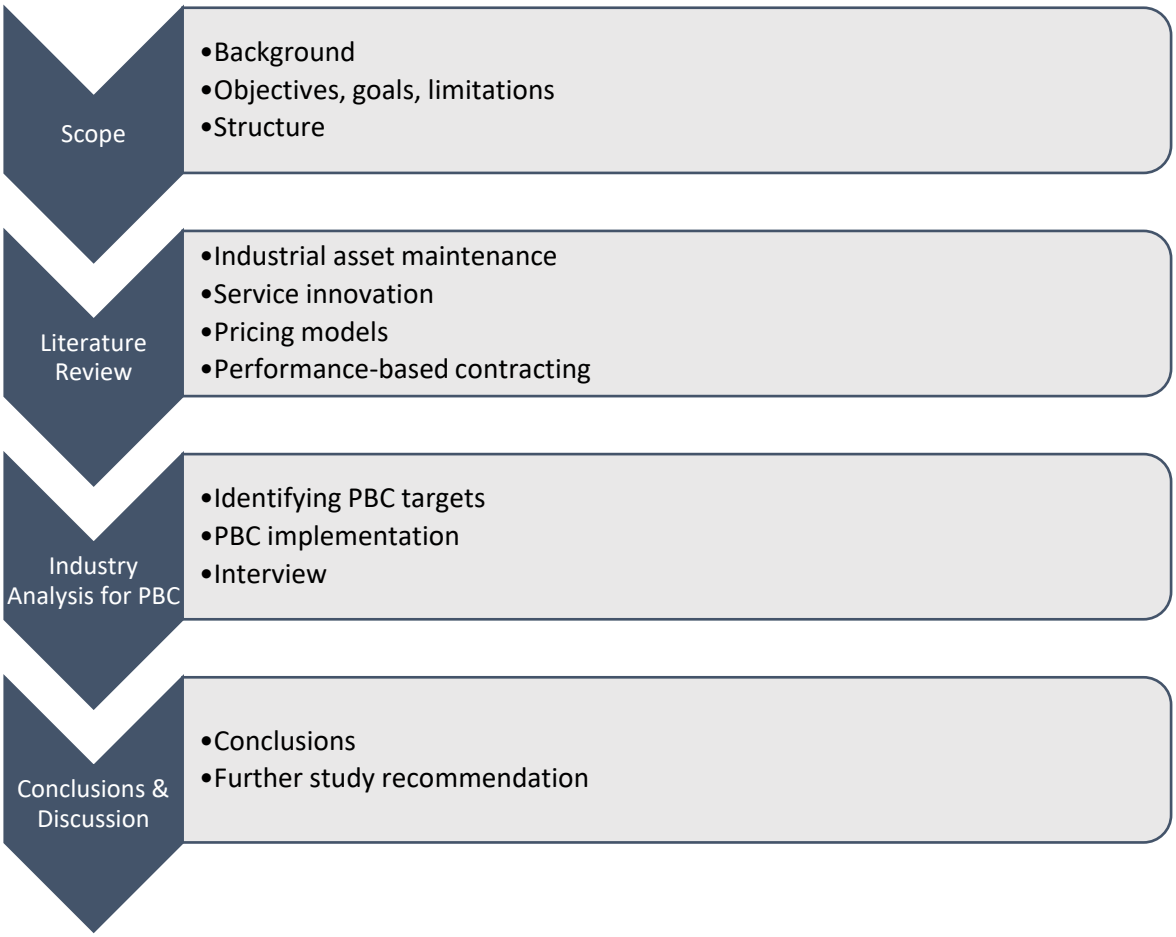

Figure 1: Research design chart

Although this thesis is closely related to maintenance, it will not go in-depth to the mechanical specifics of industrial asset maintenance. The way maintenance is physically performed varies radically between assets and industries and has no significant effect on the implementation of PBC as long as certain external and internal requirements are fulfilled.

The following chart is an input-output chart to clarify the role and purpose of each of this thesis' chapters. This chart can be used by the reader to navigate the thesis and find the correct and relevant information.

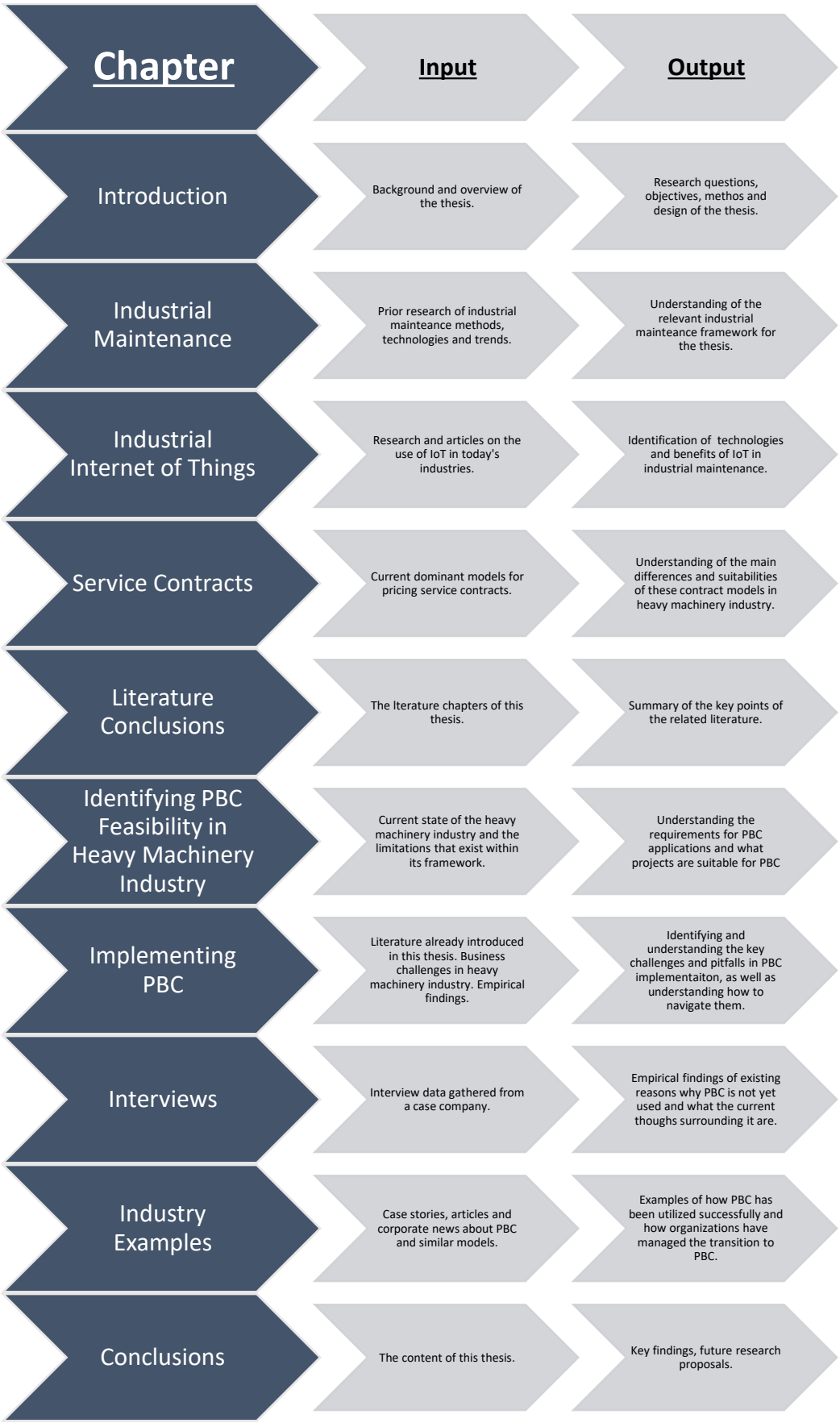

Figure 2: Input-output chart

1.2 Research Questions

The main research question of this thesis is: **How can a heavy machinery manufacturer and its client benefit from performance-based contracting?** This research question is aimed to make the reader understand the reasons and motivation behind implementing PBC in a business. To successfully answer this question, it needs to be dissected into the three separate sub-questions. First, how does a performance-based contract differ from and compare to the more traditional pricing models and contracts in the heavy machinery industry. This question will help in setting the stage for deeper analysis and for identifying both problems and advantages. After answering the first questions we are able to move to the second question of why a supplier would want to choose PBC over a traditional model, and consequently what kind of benefits and increased value the supplier can provide through PBC. It is equally important to examine this question from the client's perspective. Thirdly, we look at the challenge of implementing PBC in practice. This thesis attempts to propose a solution to how to identify a potential situation for PBC and how to successfully build an environment to enable all the benefits of PBC.

RQ1: What is performance-based contracting and how does it differ from traditional models

RQ2: Why would a supplier choose to offer performance-based contracting in heavy machinery industry?

a) What is the increased value brought to the client by offering performance-based contracts?
b) How does the supplier benefit from performance-based contracts?

RQ3: How would a service-heavy, heavy machinery manufacturer implement performance-based contracting in their portfolio in a smart way?

a) How to identify a situation where performance-based contracting can be a feasible and profitable option?
b) What makes a good performance-based contract with the client?

1.3 Methods of Research

This topic requires a literature review in the fields of business models, maintenance contracts, buyer-supplier relationship, the Internet of Things and Performance-based contracting. These theories and their applications will be analyzed by taking advantage of a large number of secondary data, such as scientific and commercial articles, case stories from companies, and academic publications.

After taking an individual look at all areas of theory, I will find the areas where they can complement and support each other to try have a more mature understanding of the context and situations were PBC can be a viable and profitable option.

The last objective of this thesis is to find ways to enable and encourage the six case companies similar organizations to implement PBC as a potential business model for some of their products. Several unstructured interviews are conducted at one of the case companies. The goal of these interviews is to find out the current attitudes and existing knowledge about PBC in the industry.

An important source of information in this thesis is the work of Dr. Andrew Jacopino and his website ‘performancebasedcontracting.com’. He has worked with PBC for most of his career in organizations as well as a consultant and actively blogs about his experiences and insight in the field of PBC.

The following keywords were used in research for this thesis: Maintenance, Equipment monitoring, Remote monitoring, Performance-based contracting, Performance-based logistics, availability contract, pay for performance, outcome-based contract, business model innovation, service strategy, IoT, Web 2.0, Supplier relationship, customer relationship, subscription, leasing, engineering, heavy machinery, Outcome-based.

Six heavy machinery companies will be used to represent the industry in analyzing the feasibility and potential of PBC. The first company, with more focus on this thesis due to the researcher's experience in the company, is Konecranes – a Finnish industrial lifting equipment manufacturer. The five other case companies are selected by trying to get some variety with other markets that share many characteristics, without branching out too far from the focus. The selected companies are John Deere, Caterpillar, KONE, GE Healthcare, and Roll-Royce Civil Aerospace business unit. These secondary case companies will not be individually analyzed in-depth, but they are included to have a broader understanding of the heavy machinery industry in relation to PBC and related services. All the selected companies, including Konecranes, manufacture, sell, and service heavy machinery engineering products with smart features and IoT capabilities. Some major characteristics for this industry are expensive equipment, heavy need for regular maintenance, and high value of low downtime of the product.

1.4 Case Companies

Konecranes Plc is a global industrial lifting equipment manufacturer headquartered in Hyvinkää, Finland. More than half of its revenue is generated by maintenance services and consultation. Konecranes has during the last years had a heavy focus on Industrial Internet, especially regarding the remote monitoring of its sold products, to identify opportunities for consultation and maintenance while also collecting valuable data for future product development.

John Deere manufactures agriculture, construction and forestry machinery, as well as core parts for heavy equipment. John Deere currently offers only protection plans and extended warranties for unexpected maintenance but has no service plans for regular maintenance upkeep. (John Deere homepage, 2019)

Caterpillar is the manufacturer of a large array of construction machinery and power units. Similar to John Deere, Caterpillar offers warranties and protection plans to their equipment. A big difference between John Deere and Caterpillar, and also the reason why Caterpillar

was included in this thesis alongside with John Deere, is the system health monitoring capabilities of Caterpillar. This enables Caterpillar to locally or remotely monitor the fluid levels, engine condition, and wear of parts in real time, and potentially prevent catastrophic failures in the field. (Caterpillar homepage, 2019)

Kone, known for its elevators and escalators in residential and commercial buildings, allows the complete outsourcing of the equipment's condition through its maintenance solutions. Not only can these solutions cover the repair and condition checks, but also allow for a 24/7 remote monitoring possibility with better maintenance prediction. Kone also offers modernization solutions to make sure the performance is kept up do date as the installed assets age in the field, and better technologies emerge. (Kone homepage, 2019)

GE Healthcare provides hospitals and clinics with many different healthcare equipment such as fetal monitors, cardiology products, probes and different medical scanners. It goes without saying that the functionality of GE Healthcare products is critical to the patient's well-being, health and even in some instances, life. However, GE Healthcare's software-heavy products come with a significantly lower risk of mechanical failure when compared to industrial equipment like construction machinery and lifting equipment. This is possibly due to the minimal number of moving parts and the lack of heavy forces applied to the equipment. Whatever the reasoning behind it, GE Healthcare doesn't offer any preventive care solutions or condition monitoring. It does still, however, offer repair services for its clients and on-demand preventive maintenance checks. (GE Healthcare, 2019)

Rolls Royce Civil Aerospace, a global aviation engine manufacturer, is famous for its innovative approach to asset sales and maintenance. The first in the industry to adopt a performance-based business model for its product, Rolls Royce has managed to successfully implement its Power-by-the-Hour®, or TotalCare®, model. Rolls Royce is a big inspiration for this thesis and is used as the prime example of a successful PBC model. (Rolls Royce, 2019)

2. INDUSTRIAL MAINTENANCE

Maintenance contracts can be designed to be either reactive on-demand maintenance or preventive maintenance. These two different types of conducting maintenance business address different customer segments and needs. Over the recent years the trend in the industrial markets has moved towards a full-service preventive model. This trend has been mostly demand-driven. (Stremersch et al. 2000)

The choice between reactive and preventive care depends on multiple factors such as failure criticality, frequency of failures, and the understanding of the importance of maintenance (Stremersch et al. 2000). In an environment where an asset failure or downtime would mean serious safety risks or financial losses, preventive maintenance is preferred. Examples of these industries include aviation, nuclear plants, and military applications. On the other hand, reactive on-demand maintenance can be a preferred choice for assets with low failure criticality, such as household appliances. The failure of a freezer or a television would mean financial losses in the range of hundreds of euros, which is not enough to make preventive care a profitable option.

2.1 Industrial System Health Management

Industrial assets have a designed lifespan, which provides a rough realistic estimation of the amount of time or usage an asset is designed to last while still being reliable, safe and functioning. As an asset's lifespan is nearing its end, organizations start looking for new replacements or alternatives for the soon-retiring asset. A shorter lifespan means shorter intervals for replacing the asset, thus increasing costs through changing costs. It is in the interest of the asset's owner to have a long asset lifespan, and one of the ways to increase it, besides from procuring high-quality assets, is to practice System Health Management and consequently be able to keep the asset in good condition.

Prognostics and systems health management (PHM), is the systematic tracking of an asset's condition, reliability and performance. PHM can predict and prevent asset failures as it

enables condition-based maintenance, instead of waiting until an asset fails or replacing parts or the whole machine on fixed intervals. (Kwon et al. 2016)

PHM, when enabled by IoT, enables the use of models and algorithms to perform prognostics and diagnostics as well as to assess the health of systems and assets. The data needed for PHM is gathered by sensors installed in each asset that track for any anomalies or failure precursors. This data is wirelessly transmitted to the cloud where models and algorithms together with the available maintenance history data, environmental data, and massive datasets of previous asset failures calculate and predict the need for preventive maintenance. (Kwon et al. 2016)

It is important to understand that PHM is only a term created to describe the principles that lie behind preventive maintenance and asset health monitoring. PHM is not a one-cure-for-all method to magically solve any and all maintenance issues.

2.2 Preventive Maintenance and Failure Mode and Effects Analysis

Preventive maintenance focuses on identifying and fixing problems in an asset before they lead to a failure and cause downtime and further problems. Replacing or repairing parts and components, that are toward the end of their lifecycle, increases asset availability and lifespan, while reducing maintenance costs. For example, monitoring the condition of the chain or wire of an industrial hoist can give clues about how reliable it is in its current condition, and help predict the time left before it needs to be changed. Not performing preventive maintenance could cause the wire to break with a heavy load, causing the load to fall and possibly cause damage to other assets or even persons. The failure of a part or component of an asset can also cause damage to other parts of the same asset, making the after-the-fact repair demand more resources what preventive maintenance would.

Failure mode and effects analysis (FMEA) and reliability-centered maintenance (RCM) are important concepts in preventive maintenance. FMEA is a method that attempts to identify all possible modes, or ways, of failure an asset can have, and then doing an in-depth analysis

of the severity of failure, probability of occurrence, and risk of non-detection for each mode. These elements are often combined to give a 'risk priority' number. RCM is a broader maintenance philosophy that includes the steps from FMEA. RCM is an idea or a framework that determines what should be done to ensure an asset reliably stays in functional condition given the current operational requirements it has in its environment. (Braaksma et al. 2012)

2.3 Maintenance Service Innovation

Service innovation is an ongoing attempt to increase the efficiency and quality of a provided service. It can mean improving the service processes, implementing new practices, or even introducing new services. Long term client-supplier relationships are an ideal opportunity for service development, as they provide a situation with longer duration of experimentation with excellent communication and access to the client and end users for testing and feedback.

According to Panesar et al. (2008), innovation in maintenance service is often limited by restrictions emerging from external frameworks such as contracts and contract law. Factors such as contract conditions, duration, and agreed terms may limit certain innovation activities from the supplier's part. Contracts are often designed based on the current situation and potential future service development activities might not be considered in the contract during that time.

It is important to construct longer service relationship contracts in a way that allows for continuous improvement in order to be able to increase operation and maintenance effectiveness and efficiency. These relationships are an excellent environment for collaboration and facilitate innovation for both parties. A successful service contract includes a clear scope of work, goals, limitations and performance indicators.

Flexibility with contracts, regular interaction, and informal conflict resolution can help in creating an innovation-friendly environment. (Panesar et al. 2008) A contract without that flexibility could lead to restricted innovation or a client-side push-back for any attempted

improvements, that could lead to failed development projects, and potentially a lost contract, while at the same time preventing movement towards more efficient processes.

2.4 Supplier Selection

When making an asset purchasing decision, an organization has many factors to consider regarding which supplier they purchase an asset from or sign a maintenance contract with. Usually this this decision is done on multiple levels of an organization. Choosing a suitable supplier can bring significant benefits such as higher asset availability, increased product or service quality, lower costs, and faster response time. The most used criteria in supplier evaluation in the engineering industries, according to Ho et al. (2010), are product quality, delivery, maintenance, service, price, relationship and risk. According to an older industry study by Vyas and Woodside (1984), price was the most important factor in maintenance supplier selection, but only after the minimum quality, delivery and service requirements were met. However, Vyas and Woodside point out that the combined effect of these 'secondary' criteria could outweigh the more affordable option, if they improve the situation enough. This is an old study, but there is no reason to think the basic principles of supplier selection decision-making have had any major changes over the last 35 years.

An interesting point here is that "Price" could mean different things with different business models. The scope during which the "Price" is considered can vary between clients. Subscription models will always have a lower price than a capital investment in an asset, if only looking at a short timeframe. It is important to understand the costs of the whole lifecycle of an investment.

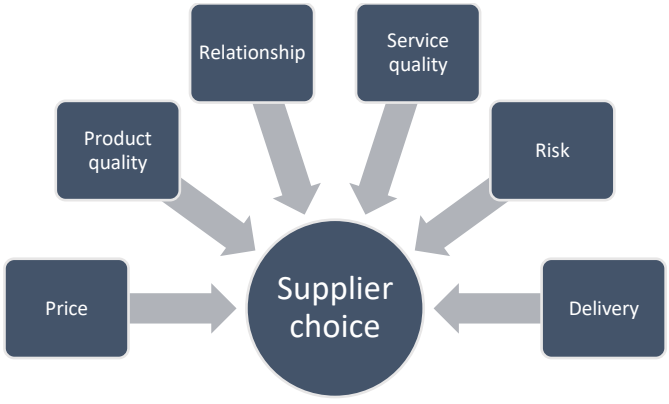

Figure 3: Main factors in industrial supplier selection

3. INDUSTRIAL INTERNET OF THINGS

With the advancements of network technologies, the pursue of efficiency, and the cost of technology having gone down, devices and machines have started communicating with each other more and more over the last years. This technology is called the Internet of Things. While familiar as a phrase and concept to companies in virtually every field, it still has somewhat of a reputation of a buzzword used by brands and companies in their marketing.

The number of devices, or 'things', connected to the internet is showing no signs of slowing down its growth, but instead quite the opposite. It is estimated that by 2020 the IoT-based smart home industry alone will each a market size of 53 billion dollars, whereas the whole IoT industry would be an industry between 1,9 and 60 trillion dollars. (Albert, 2018; Hossain, S. M. et al. 2016)

However, consumers are not the only ones benefitting from this new technology. In fact, businesses have already started to take advantage of the real-time data, remote monitoring, and improved decision making made possible by combining IoT with Industrial Internet (II), forming a mouthful of a term, Industrial Internet of Things, or IIoT. The IoT brings a paradigm change to the industry that allow organizations to pursue totally new business opportunities across all sectors. (Kwon et al. 2016) IoT allows organizations to use the real-time data flowing it from multiple sources to monitor and track exactly what is happening in real-time. This paradigm enables automated processes, the use of AI, and overall faster response times.

Gubbi et al. (2013) argue that the value of IoT in the near-future will increase radically and is only limited by the creativity of those finding, designing and developing new IoT applications.

3.1 Cross-device Communication

One of the key aspects if IoT is cross-device communication. This simply means that machines send, receive, and process data with each other without the involvement of a human. The aim of cross-device communication is to offer more real-time data and increase efficiency with automation in different tasks freeing humans to focus on more challenging and creative tasks. (Gubbi et al. 2013) For example, a warehouse that uses IoT- connected inventory sensors can automatically send an order request for any parts that are running low. This guarantees part availability and frees warehouse employees to perform more demanding and productive tasks.

3.2 Remote Monitoring

As connectivity and sensors keep getting more affordable, companies can transmit many kinds of data from almost any equipment to anywhere in the world. Remote monitoring is available anywhere from airplane engines to industrial lifting equipment to automobiles to medical equipment.

The data gathered can also be used in a way that enables organizations to have a whole new service business model. Remote monitoring enables manufacturers to remotely track performance, reliability, usage, or any and all activities. According to Kwon et al. (2016), the performance and reliability of industrial equipment is still largely estimated, measured and predicted by industry experts and consultants. The involvement of humans slows down the decision-making chain required to evaluate and analyze the need for maintenance.

3.3 Implications of IoT in the Industry

IoT allows companies to perform diagnosis and prognosis on any assets in the field. Physical occurrences like vibration, bending and heating can be recorded using sensors, sent to the cloud to be analyzed my automated systems, and them be used in preventive maintenance. Remote diagnosis and prognosis can help maintenance personnel in arriving at the facility with an enlightened idea of the issue and being well prepared for it.

One of the best information and data sources for R&D is the end-user. IoT allows manufacturers to accurately monitor how their equipment is used and what are common problems users encounter. This data is an incredibly valuable tool for developing new products and services, as it is completely unbiased and fact-based.

IoT and data collection also act as a channel for generating more sales and consultation leads. For example, identifying situations where certain functionalities of a piece of equipment are seldom used or used wrong, could be a sales lead for consulting services or training about said functionality.

When faults are observed, proper sensors and cloud-based analytics can help the manufacturer in identifying what series of events led to a failure, and either use that data in further development, or if applicable, offer training or consultation services to the client in order to minimize the risk of the same kind of failures.

4. SERVICE CONTRACTS

When purchasing a car, it is clear for all involved parties that the car will require maintenance later, no matter how properly and "by-the-book" it is operated by the owner. No maintenance-free machines exist. Yet, the car is sold as a physical product with a fixed sum, and any service required later will be purchased by the owner from separate service shops. Even in service-heavy industries, the service and maintenance costs are not included in the total price of the product. The maintenance services have been traditionally based on fixed sum contracts. For example, individual maintenance activities or service packages would have a pre-determined price. Another, still traditional, way of pricing maintenance services is called cost-plus, where a fixed premium is added to the supplier's costs. Maintenance can also be sold as subscription. Subscription models are the more modern models of these three.

4.1 Fixed Sum Contract

In a fixed sum contract the contract's financial risk is placed fully on the supplier. Fixed sum maintenance contracts require the customer to own the product. Therefore, this type of contract can be seen as two separate contracts; the asset purchase contract, and the maintenance contract. This leads to a supplier's incentive to achieve cost efficient maintenance, but what it does not incentivize, is the supply of high-quality service, process improvement, and good long-term maintenance and modernization. Instead, it incentivizes low-cost maintenance and infrequent visits. This is due to the fixed sum contract supplier's natural motivation to visit the client for services often for repeating business and increasing profits. If something outside of the contract terms is needed, the client will have to purchase extra services for additional cost.

Traditional fixed sum contracts are easy to understand, construct and negotiate. They are the simplest form of physical service or product trade. When an asset is inspected, gets preventive maintenance, or is repaired, a fee is charged to the client based on the resources used.

For the supplier, earning enough income to break even or make profit at the point of sale is favorable, since the sooner profits are received, the sooner new capital can be invested in new projects, allowing funding for future projects and investments. Making profits on the asset sale places the investment on the client. The fixed sum contract for maintenance does, however, enable lower maintenance fees as the supplier has already generated net profit through the asset sale and does not need to charge high maintenance fees to break even.

Large payments at the point of sale act as an additional barrier for purchase, as the buyer needs to be sure about the profitability of the investment. The buyer always faces certain uncertainty and risk when committing to a large investment. These risks include faulty products, higher than expected asset downtime, the product not matching expectations, and bad customer service and maintenance later. A large lump-sum investment in the supplier's equipment also places the client in an unfavorable position for negotiating maintenance contracts, are they are financially tied to the asset investment.

4.2 Cost-Plus & Time and Money Contract

The cost-plus model for maintenance contracts places the financial risk on the client. No matter how much the cost for the maintenance is, the supplier will charge the cost plus a fixed-rate premium for each activity or service performed. This business model will require the client to purchase the asset and place the risk of investment on themselves. Cost-plus contracts are sometimes referred to as Time and Money Contracts. According to Spring (2010), the cost-plus model gives no incentive for the supplier to develop more cost-effective maintenance as that would decrease the cost for the client, due to the nature of the cost-plus agreement, thus keeping profits the same. Cost-plus contracts create an environment where the profits of the supplier will stay the same no matter how much value the client receives from the services. Even by developing better and more cost-efficient maintenance practices and processes, the net profit will remain the same. This also works the other way around: the supplier can in fact be as cost-inefficient as it wants, since the increased costs will always be covered by the increased fees. This is an uncomfortable situation to be in as the client.

4.3 Subscription Model

Subscription models are based on the idea that the client subscribes to a functional product. With the subscription model, the maintenance and the product cannot be separated. The client will pay a recurring price at regular intervals in order to have access to the product. The benefits of a subscription model for the client are the transfer of responsibility to the supplier as well as the stable cashflow from recurring payments, instead of paying lump sums at the moment of purchase. Subscription model brings an incentive to the supplier to maintain a high-quality functional product in order to keep existing clients and keep their asset's maintenance cost-effective through systems health management and preventive maintenance. Subscriptions lower the client's risk as they do not tie up capital in the asset. This model also makes cashflow predictions extremely simple and accurate, as the costs will be fixed and constant. It does, however, still retain the risk related to low asset use. It does not matter if the asset is performing only 2 hours a week, it will still cost the client the same as if it would be used 50 hours a week. For this reason, the subscription model favors the heavy user client.

The subscription model has been gaining popularity over the last years, especially in the software industry. More and more companies are moving to subscription models, although it means lower profits and higher costs for the duration of the business model transformation. Once completely implemented, the model offers increased stability and predictability in terms of cashflow. (Tzuo, 2019)

4.4 Performance-Based Contracting

Performance Based Contracting has many names. Some of the more down-to-earth terms are pay-per-use and pay-by-the-hour. Common industry terms also include Pay for Performance, Performance-Based Logistics, Outcome Based Contracting, and Rolls Royce's famous Power by The Hour model it uses for its aircraft engines. Broadly defined Performance-Based-Contracting (PBC) means having the client pay for the amount or quality of the outcome of a product or service, rather than having a fixed one-time or recurring price (NIGP, 2012). A simple example from the consumer world would be an electricity contract with an energy company. Instead of paying a high amount of money up-front for a specific

amount of kilo watts to be used whenever, the client is charged per each kilowatt at the end of each billing cycle. This means that when the power goes out for the client, the energy company cannot generate any income from that client. The energy supplier has the incentive for making sure the client has access to their product.

Performance-based contracting offers a paradigm shift in how assets are owned and maintained. In PBC the payment is based on the results or performance, instead of the resources used. PBC offers many benefits, but also requires organizational and cultural changes in both the client's and the supplier's organizations. When successfully implemented, PBC can help with many of the problems and challenges that come with industrial asset sales and maintenance. Companies can better divide the risks in a way that constitutes mutual trust, as the supplier has their own profits directly influenced by the reliability of the sold asset.

Identifying the right projects and assets for PBC is a critical factor in finding feasible areas to implement PBC. The major drivers for PBC are the accurate measurement of performance, failure criticality and supplier expertise.

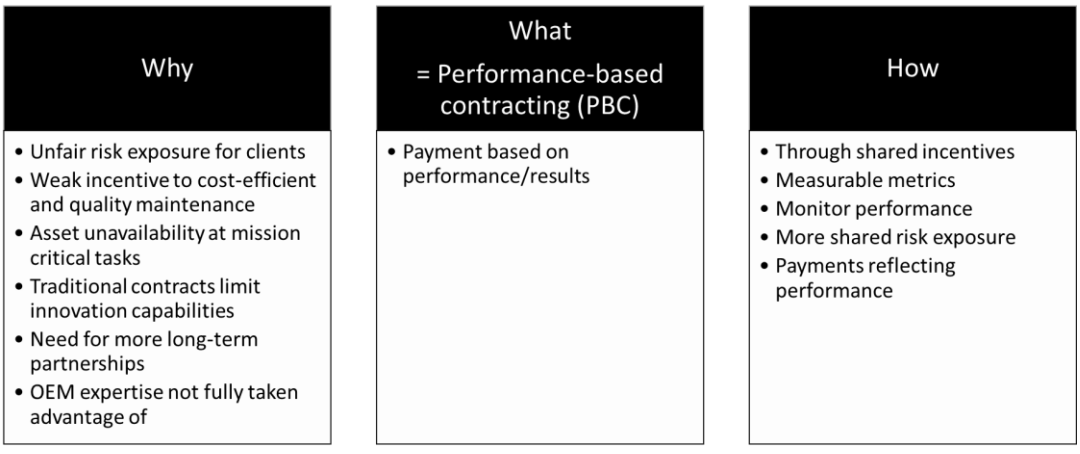

Figure 4: Why, what and how of PBC

Benefits and Enablers

The benefits of PBC for the client are clear and immediate. When paying the supplier an ongoing fee for having an asset or a device producing output, the incentive is for the supplier

to provide a high-quality product or service that translates to a low downtime as well as low maintenance costs. This more equally allocates many of the risks that come with investing in expensive assets and service. With traditional cost-plus and fixed-cost maintenance contracts, that come with traditional asset sales, the risk is more unequally distributed. (Selviaridis and Wynstra, 2015) Wharton (2007) also argues, that PBC can lower the lifetime cost of an asset for the client.

For the supplier, however, there are many benefits as well. As PBC payments are based purely on the performance of a product or service, it gives the supplier autonomy in decision-making and operations. The granted autonomy allows the supplier to choose the best ways for approaching each project, and the development of service processes as well as the asset itself. One of the benefits is the fact that, in the age of IoT and big data, customer data is incredibly valuable as data-driven decisions are better (McAfee et al, 2012). By monitoring an asset's performance, the supplier has access to a vast array of use and condition related data. This data can be useful for research & development as well as sales. For example, analyzing failure trends can help the supplier in identifying potential leads for consultation and asset retrofitting/customization.

There is an inherent risk in all capital investments, procuring an industrial heavy machinery asset being one. With a large up-front lump-sum payment, the client has the risk of losing theoretically the whole amount of that investment, plus losses in production, if the asset doesn't meet the standards or requirements. As the payment scheme with PBC is directly tied to the outcome, or performance, of the product or service purchased, clients can have significantly more accurate investment calculations, as the investment will only cost the client when it is used. As long as the asset is costing the client less per performance unit that what it produces in monetary terms, it is a profitable investment. In other words, if the PCB contract specifies a fee of X Euros per an hour of operation, and the asset outputs a value of 1,5x Euros per hour of operation, the investment has a positive net value.

Asset Reliability

Counting on the original equipment manufacturer (OEM) to be responsible for the condition and performance of an asset, means the supplier can fully take advantage of its expertise related to the asset in questions, thus increasing the asset's reliability, when compared to a third-party servicer.

According to Guajardo et al. (2009), the most well-known private industry implementation of PBC, Rolls Royce's Power-by-the-hour, has improved the commercial aircraft manufacturer's product reliability significantly. The MTBR, or mean time between removals, had increased 10 – 25% after introducing PBC. Mean time between removals is a key maintenance metric used in aerospace and defence industries. It is the average duration between an aircraft engine needs to be removed for maintenance purposes.

Supplier Innovation

As Sumo et al (2016) and Panesar et al. (2008) point out, a service contract's high term specificity, meaning the degree to which the practices and ways of performing service-related tasks are controlled and regulated by a contract, acts as a restricting factor for supplier innovation. By opening up the contract to have a significantly lower term specificity, PBC grants the supplier greater autonomy leading to daily operations innovation and the development of processes for a given service, such as maintenance. Not only does PBC allow for supplier innovation within the contract's duration, but it also encourages it, as higher efficiency and improved quality often lead increased profits and customer satisfaction.

However, low term-specificity and PBC payment model alone do not automatically result in higher supplier innovation. According to an IT industry case study by Sumo et al. (2016), PBC's two main characteristics, which are low term-specificity and higher rewards for better performance, are a requirement, but not a guarantee for supplier innovation. The case study found that even with PBC, supplier can struggle to innovate in their service. One of the big problems was the fact that even with low term-specificity, the client company was not granting the supplier the real autonomy it should have had. The client monitored and

restricted the supplier's decision making in day-to-day operations partly due existing IT-infrastructure and partly due to previous problems and interactions with the supplier. Sumo et al. (2016) also identified the risk-averseness of a supplier an important factor in a supplier's ability to innovate under PBC. A highly risk-averse organization does not have the needed risk management processes and expertise to function optimally under the supplier's risk exposure brought by PBC.

The development, however, is not limited to the service and maintenance processes, but the supplier has the possibility to introduce improvements to the asset itself, increasing its performance or decreasing its maintenance need.

Supplier-Client Relationship

As PBC transfers much of the financial risk from the buyer to the supplier, this should have a significant positive effect on the client's relationship to the supplier, assuming the overall cost is kept comparable to conventional maintenance contracts, and asset downtime is kept to a minimum, which is in the interest of both parties. PBC also enables the supplier and the client to have a more long-term and mature relationship which makes it easier to align both sides' interests and better understand the expectations and goals of both sides through dialogue. (IACCM, 2015) PBC shows the supplier's trust in their own products and services, as they are prepared to lose profits when the product is not performing.

PBC simplifies the aspect of warranty. Warranty is no longer required in its traditional form as the ownership never changes. Instead a term could be introduced in the PBC contract, where the inability of the client to produce any performance using the asset over a agree-upon period of time, would either terminate the contract, or cause the supplier to compensate the client for the losses. However, this is a theoretical situation, as it is in the interest of both parties to ensure the high performance of the asset, and a situation where the asset is not generating any profit is a situation where both parties should agree on terminating the contract.

Challenges and Barriers

While there are pervasive managerial and analytical arguments that support the idea that PBC leads to more effective value creation, lower costs, higher profits and higher performance levels, the empirical evidence as of today is somewhat non-existent. One of the largest cases of PBC implementation is the United States Department of Defense, which has in multiple interviews and studies expressed that PBC has had a significant positive effect on their operations. However, the United States DoD has not gathered or released any empirical data for analysis of the effects of PBC.

Sultana et al. (2012) identify seven issues for the client to consider before introducing a PBC solution to a problem. First, the performance must be measured in a standardized way for payment and quality assurance purposes. The performance metrics chosen must reflect the goals and desired results, instead of steering the contractor towards any specific method of working, as the metrics used to measure performance are directly linked to payment and quality monitoring.

Second, the expertise of the supplier is another major factor to consider before agreeing to a PBC agreement. As PBC is normally implemented in environments where high asset availability is desired, and failures are critical, it is important for the supplier to have the expertise required to reliably perform maintenance-related tasks to guarantee reliability.

Thirdly, identifying the specific projects where PBC implementation would bring increased value. For example, with road maintenance, the tasks can be divided into individual activities, such as mowing, lighting maintenance, pothole repair or crack sealing, which can be individually contracted with simple contracts. On the other hand, the total condition of the road can be contracted with a more comprehensive and complex contract that covers all the sub-systems of the road, like lighting, gravel and grass. The client is responsible for identifying the most suitable areas of implementing PBC.

Fourth, the risk exposure will be rebalanced as soon as PBC is introduced. The client's risk exposure will decrease as the supplier's will increase. This is due to the fact that payment to the contractor is tied to asset performance that is solely (except in case of the client knowingly neglecting safety or operation related guidance) at the responsibility of the supplier. However, allocating more risks to the supplier will only be beneficial to both parties only when the supplier's expertise and capabilities are better than the client's. The fifth issue is one of the most important ones, as it points out the importance of performance monitoring.

As the first issue points out the importance of the right metrics, the fifth relates to how those specific metrics are monitored. Things to monitor can include for example service quality, timeliness of service, safety and cost-efficiency. This issue links closely to the first one.

Sixth, the employee issue. Most of Estonia's road network is maintained using PBC agreements. The number of employees in Estonian road agencies declined from 2 046 to 692 during the four years after 1999, when Estonia began heavily introducing PBC in its road networks. This is because PBC models require less administrative work than conventional maintenance agreements.

The seventh and last issue regarding PBC is the payment and termination of the contract (Sultana et al. 2012). In the graph below are the seven issues related to introducing PBC in an organization's operations.

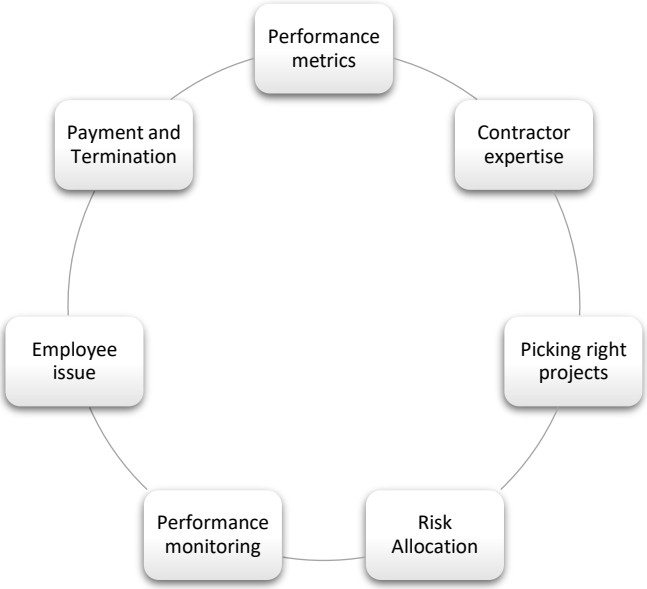

Figure 5. Seven issues for the client in PBC implementation

Many of the challenges with PBC relate to uncertainty in one way or another. Other noticeable challenges are defining clear areas of responsibility, the complexity of contract negotiations, a high level of coordination and the need for efficient exchange of information (IACCM, 2015).

The challenges with PBC are mostly avoidable through mature and well-developed processes and management. Naturally, when introducing any kind of innovation, there will be an immature period where all stakeholders are still gaining understanding on how to gain optimal mutual benefit, and how to develop the related processes to achieve a more mature and sustainable model. This can be achieved through continuous learning and smart process development. The involvement of IoT can offer significant benefits to many of the issues, such as performance monitoring, metrics and communication.

The challenges presented up to this point relate to the technical and business side of the transition to PBC. It is important to understand that while other industries, such as software, can be welcoming to new trends and more readily welcome innovation and change, some industries have somewhat conservative mindset towards taking risks and changing their ways. An often-forgotten challenge that stands in the way of many feasible, viable and potentially profitable innovations, or changes in general, is the existing culture of an

industry. The manufacturing and logistics industries are traditionally seen as somewhat conservative industries, where change is slow, and innovation is met with doubtful looks. Introducing a radical change in how work is done and what tools must be used is not only an internal problem, but radical changes and innovation must also be successfully marketed to the partners. An idea such as PBC would mean the redesign of many job descriptions, responsibilities and titles. In addition, selling a new kind of a service, no matter how viable technically, will always be a challenge in conservative industries, such as the heavy machinery industry.

PBC requires a clear consensus between both parties about the risk exposure. In case of Force Majeure or client's neglect, the contract must be extremely detailed to cover in which events the asset downtime is at the supplier's responsibility. Force Majeure refers to events beyond either party's control, such as storms, strikes, crises and earthquakes. If downtime occurs as a result from regular use, we can assume the supplier is responsible for the repair. However, in an instance where faults keep occurring regularly due to improper use and lack of training for operators, it is not as clear whether these repairs would be covered by the contract. The clauses on the PBC agreement can dictate if operator training and downtime caused by improper use are the supplier's responsibility.

5. LITERATURE CONCLUSIONS

Industrial maintenance has a set of frameworks and philosophies that are used to effectively tackle the problem of degrading, wear, and other mechanical problems that arise in assets. Industrial systems health management as a holistic view that utilizes preventive maintenance and failure mode and effects analyses to build a solid framework inside which a supplier is capable of promising and providing quality service and maintenance.

The Industrial Internet of Things, or more specifically remote monitoring and cross-device communication, make industrial systems health management possible on a large scale by enabling remote data collection and centralized analytics through cloud-based data management and algorithms. This technology allows companies to detect abnormalities and signs leading to a failure in real time and react to them anywhere in the world. IoT increases the scalability of prediction-based preventive maintenance business due to the economies of scale with cloud computing and data management.

The three main business models for industrial asset and maintenance packages are fixed sum, cost-plus, and subscription. PBC would be categorized close to subscription, but it has some major differences. Both fixed sum and cost-plus are generally used as separate maintenance contracts after the asset has already been sold and thus normally require the client to own the asset. Subscription contracts allow clients to pay fixed recurring fees to have access to an asset. Service is normally included in subscription contracts. With subscription, the client does not own the asset. PBC is based on recurring fees same as the subscription model, but generates income based on asset performance, not time.

Traditional maintenance contracts have a limiting effect on a supplier’s innovation capabilities. The external limitations and restrictions that arise from contract terms and legalities can act as barriers for the supplier in introducing new ways of working, process development, and even in implementing physical improvements and new features.

The supplier selection process is complicated, varies by organization, and sometimes results in idiosyncratic decisions, but the overall biggest factors are product quality, service quality, price, delivery, existing relationship, and risk. As long as all the other factors are fulfilled to the minimum approved level, price will usually be the ultimate deciding factor.

6. INDUSTRY EXAMPLES

PBC has been utilized by companies and organizations before, although with different names. Naturally, since PBC incentivizes high quality equipment and excellent preventive maintenance, we can trace its origins to where unexpected equipment downtime is a matter of life or death; the armed forces. A later commercial adaptor was Rolls Royce with its plane engines.

6.1 United States Military

The United States Department of Defense (2016) describes in its PBC-related guidebook how it has been using performance- based contracting as their preferred sustainment strategy in the field since 2001. The motive behind PBC for the Department of Defense has been the compress supply chains and provide improved reliability and readiness at an affordable price.

The United States government has identified five areas where the Department of Defense utilizes PBC and estimates that by broadening the application of PBL in these areas, the Department of Defense could bring down its readiness, maintenance and operations costs by $32 billion annually. This constitutes to 10-20 % of the department's maintenance budget, depending on what is included in maintenance. (Spring, 2010)

Taking advantage of PBC arrangements is the Department of Defense's attempt at coming out of the "death spiral" as described by Spring (2010). The "death spiral" is a cycle where older aging weapons and inefficient systems cause the military to spend more on maintenance and support, which diverts defense budget to maintenance activities. This in turn results in the procurement of less expensive weapons and systems that are more expensive to maintain. By lowering the maintenance costs, the Department of Defense could reallocate that saved money from the budget into procuring higher quality and more efficient weapons and systems, that would in turn be more affordable to maintain, consequently freeing up more resources for procuring better quality.

According to the Department of Defense (2016), a properly structured PBL (Performance-based logistics is the U.S. government's term for PBC) arrangement works by balancing the needs of the government with the needs of the Industry. The government is interested in procuring quality products and services at an affordable price, while the industry's main interest is to meet its responsibility to its shareholders by achieving all potential profits. The Department of Defense has managed to construct its PBL arrangements in a way that allows them with higher or equal levels of warfighter availability at a lower cost per unit of performance. This furthermore increases when at contract renewals, a new-cost based contract is structured to further reduce the government's costs. The industry is able to drive down its cost of delivery to the Department of Defense with long-term arrangements and thus being able to improve the corresponding supply chain activities and processes. The industry also has a more stable revenue flow due to the long-term PBL arrangements.

Department of Defense (2016) also notes that moving to a PBL arrangement does not automatically mean that all work is performed by the commercial PBL supplier. In some cases, certain activities should still be performed by the government workforce in order to guarantee high availability and efficiency of the warfighter. Understanding which work activities to move to the PBL supplier is a critical part of structuring an optimal PBL arrangement.

6.2 Rolls Royce – Power by the Hour

The Rolls Royce Civil Aerospace business unit is famous for its early commercial adaptation of the PBC - although sometimes incorrectly referred to as subscription - model into its aircraft engine maintenance. Rolls Royce charges its customers based on the number of hours its aircraft engine is running and assumes all maintenance related tasks. PBC is fitting for their business as failure criticality is extremely high regarding commercial aircraft. The complexity of maintenance is high, and as the original equipment manufacturer Rolls Royce is equipped with the required expertise to take on that responsibility.

As pointed out before, Rolls Royce had managed to implement PBC in a way that enabled them to function at increased cost efficiency, while increasing their engine reliability and lowering the mean time between engine removals by up to 25%.

6.3 Car leasing (Kilometer based)

PBC could be compared to a lease agreement on a car. Traditionally car leases have a specified maximum number of kilometers the client can drive with the car per a period of time. Any kilometers above this limit will cost the client extra. The main difference in lease and PBC pricing is that with leasing, the client shouldn't go above the maximum kilometer limit as those extra kilometers will be heavily penalized. With PBC, the baseline performance fee (or required yearly performance) only exists to minimize the risk of financial losses for the supplier. The client in PBC is expected to go over the baseline. As a PBC client, reaching and going above the required hours is preferred, whereas with a lease agreement, you want to avoid reaching the maximum kilometers.

If the car suffers from a failure during the lease period, the maintenance will be covered by the leaser. Sometimes lease agreements include upkeep maintenance in the contract, but it does vary between leasers. The reason organizations often opt for lease agreements is to avoid the risk and investment in a depreciating asset. leases guarantee a stable cash-flow and simplify financial planning.

6.4 Intercity Express Programme

The intercity express programme (IEP) in the United Kingdom is programme with a goal to procure new trains for UK's East Coast Main Line and Great Western Main Line. These new trains are to replace the older fleets and are provided and serviced by a Hitachi and John Laing Investments run consortium: Agility Trains. Agility Trains and the UK Department of Transportation, or DfT, have constructed an availability-based contract, where the payment by the franchised train operators is based on the number of days each train is available for operation. The DfT guarantees a 27-and-a-half-year usage of the Agility Train's equipment. This contract is estimated to be worth 2,1 billion GBP, which is roughly 2,3 billion Euros. It

is said to be the biggest privately financed rolling railway equipment deal in history. (Railway Gasette, 2014; McLoughlin, 2012)

Availability-based contract is a sub-set of Performance-based contracts. The name already implies the metric used for performance; availability. Availability-based contracts work by promising the client 100% availability for an agreed recurring fee and giving the client deductions or credits whenever availability targets aren't met. Availability does not necessarily mean only the physical functionality of the asset but can also be expanded to mean for example cleanliness and presentability. In the IEP case, the cleanliness is included in the contract (McLoughlin, 2012).

6.5 Estonian Infrastructure

The Estonian Road Administration, or ERA, decided in 1995 pilot the outsourcing of road maintenance to private companies under PBC contracts, as an alternative to in-house road maintenance. With several 1-year and 2-year PBC contracts in 1995, the ERA noticed the improvement in road quality in these selected areas. At the beginning of ERA's PBC pilot, 50 % of Estonian road users considered the condition of the Estonian roads good or very good. Four years later this number had climbed to 76 % in the areas where PBC had been implemented. ERA has also been able to operate on much lower workforce due to private companies handling road maintenance, and due to not requiring as much staff to supervise these performance-based contracts and perform administrative tasks. Since 1995, the ERA has moved on to make up to 7-year PBCs, and the entire 16,500 kilometer road network under the ERA is not maintained through PBCs. (Asian Development Bank, 2018)

The growth trend in the number of PBCs the ERA has done with private contractors shows that ERA has seen the value in PBC and sees it as the preferred way to do business.

6.6 Discussion

As multiple examples show, PBC is no longer a theory or a one-time occurrence with Rolls Royce's Power-By-The-Hour. This business model has shown its potential on multiple occasions across many different industries where maintenance and performance are in a

critical role. These examples tell us that the feasibility of PBC in heavy machinery industry is no longer a question of whether it could work, but instead what it can be applied to.

There are dozens of more examples publicly available online, most of which are related to infrastructure is developing countries.

7. IDENTIFYING PBC FEASIBILITY IN HEAVY MACHINERY INDUSTRY

As the literature has demonstrated, the main external elements influencing PBC feasibility are failure criticality, performance measurement, maintenance complexity and the supplier's physical access to the asset.

Failure criticality: One of the major incentives for implementing PBC is a situation where an asset's failure would cause significant financial losses or safety risks. Examples of failure critical industries include mass transportation, nuclear energy, automotive, and chemical process industries.

Performance measurement: The most limiting factor for PBC is the immeasurability of performance. For example, in the automotive maintenance industry, the easiest metric to measure would be the distance driven, but the distance does not accurately reflect the wear and deterioration of a car. There is significant variance in how drivers drive their cars, what kind of roads the driving happens on, and what kind of a climate the car is kept in. It would be extremely difficult or impossible to standardize PBC agreements in an industry with so much variance between clients.

Maintenance complexity: A complex asset that requires deep knowledge and expertise to properly maintain is not only an incentive for favoring original equipment manufacturer's (OEM) maintenance services, but also for PBC. Offering PBC for the client is a sign of trust in the supplier's own service quality. According to Rolls Royce the main element clients appreciate with PBC is the reliability of the asset. As the original manufacturer, the OEM has the most information and expertise available, which allows the supplier/OEM to be in the best position to guaranteeing the highest reliability possible. Many organizations even go as far as completely rejecting third party maintenance offers due to their lower quality standards.

Supplier's physical access to asset: In order for PBC to function properly, the supplier does not only need to be able to accurately measure the performance and results of an asset, but also the physical access to the asset. Remote prognosis and maintenance planning will only go so far, if immediate access to the asset is not available. For example, with agriculture assets like tractors and harvesters, the location of an asset can be extremely difficult to reach for maintenance personnel. Not only does the location of these assets change constantly, but they can be far away from cities, deep in a forest where proper road network does not exist. In comparison, Rolls Royce can always be sure their engines can be found in airports, where the connections are designed to be extremely efficient and accessibility is not a problem. In this case the location is also predictable, as airline operators plan their routes and schedules well in advance.

Table 1: PBC feasibility assessment table for heavy machinery manufacturers

Name	Product type	Failure criticality 1-5	Ease of performance measurement 1-5	Maintenance complexity 1-5	Supplier's physical access to asset 1-5	Sum	Average
Konecranes	Industrial cranes, hoists, forklifts	4	4	4	5	**17**	4.25
John Deere	Forestry/agriculture vehicles	2	2	2	2	**8**	2
Caterpillar	Construction and mining equipment. Industrial engines and turbines	2	2	2	3	**9**	2.25
Kone	Elevators, escalators	4	4	4	5	**17**	4.25
GE Healthcare	Diagnostics imaging equipment, healthcare equipment	3	1	4	4	**12**	3
Rolls Royce Civil Aerospace	Aircraft Engines	5	5	5	4	**19**	4.75

The table above provides some understanding about the elements that increase or decrease the suitability of PBC. By using the elements presented earlier we can calculate an estimate of whether or not PBC could potentially be a profitable model in the industries of the selected companies. The numbers selected are selected based on the researcher's understanding of the industries and products.

We can observe that the companies with the highest scores are Rolls Royce (19), Kone (17), and Konecranes (17). It makes sense that the company with an already active PBC offering has the highest score. The lower scores of John Deere and Caterpillar give us an idea that their industry might not be suitable or performance-based contracting in maintenance.

Using the scoring system in the table above we can roughly deduct that Kone and Konecranes would have potential for taking advantage of the PBC model in their offering. Both these companies share many of the elements that made PBC a feasible and profitable long-term model for Rolls Royce. All three globally manufacture and service highly mission-critical technological heavy equipment that require on-going preventive maintenance over a long period of time, even up to 10-15 years, before going obsolete.

8. IMPLEMENTING PERFORMANCE BASED CONTRACTING

Implementing the PBC model in an organization is not as simple as marketing the benefits of this new contract type to clients and then entering into these contracts. PBC requires a deep analysis of the supplier's internal capabilities, the client's readiness, and of the relationship between them both. In this chapter we will look at the drivers behind implementing a performance-based contract in a supplier's portfolio, as well as the main areas of focus for a successful PBC. The heavy machinery asset supplier's capabilities for PBC include performance measurement, efficient prognostics and diagnostics, the ability to handle risk, and an innovative culture that fosters continuous improvement. The client, however, must be willing and able to give up that control of their asset and its maintenance. A sufficient autonomy is a requirement for any successful PBC. The relationship and contract must cover a well-designed and fair system of payment that doesn't place either party at an unfair risk disadvantage.

8.1 Client Environment

In mission-critical industries, where low equipment downtime is of extremely high value for the client, PBC can help clients as they can be increasingly assured that they are getting the best possible uptime and maintenance the supplier can provide, as high uptime serves the interest of both parties. Industries, where downtime is not a significant concern, may have a higher preference towards calling in maintenance after the fault has happened. An example of a non-mission-critical asset would be a cash register at the checkout of a large store. Assuming one of them fails, there is no concerns of the user's safety or financial losses, as the store customers can be redirected to alternative checkouts. In cases like this, maintenance would be called on site after a failure is observed. Alternatively, examples of highly, mission-critical-assets would be mass transportation vehicles, nuclear plant cooling system, and military equipment. A severe failure in this kind of assets could be catastrophic both financially and socially.

The inability to perform maintenance with the client's own in-house technicians is not directly a driver for the suitability of PBC, but it forces the client to outsource maintenance. This creates a potential lead for offering the PBC model. The client's inability to service the asset can happen naturally or artificially. The natural way would be simply if the customer's cost structure will not allow for in-house technicians, or the equipment has too specific and new technology, so that its maintenance requires specialized expertise. This situation could also be achieved by purpose, for example by implementing software in the equipment, that needs to be accessed by licensed service personnel, in order to perform maintenance tasks, as often seen in the automotive industry. For example, modern cars' software can only be accessed for maintenance by licensed professionals.

Low equipment use time per day or week is another factor steering the client towards PBC. It makes financial sense for the customer to only pay for the use time of a piece of equipment they are only using a few hours a week, instead of renting the equipment and paying the same amount as they would be paying if they used it 24/7. Naturally, this same factor has a discouraging effect for the supplier, thus a balance needs to be found in a contract.

8.2 Performance Measurement

The measurement of performance is a critical part of a successful PBC contract. While some industries and products can be measured by hours of operation, others must be measured with different performance metrics. There is no single right answer as to what the correct metric is, but it should be chosen by experts who understand what fits for the equipment in question. A good performance metric for PBC accurately reflects the relationship between the use of the machine and its need for maintenance.

For example, using meters moved as a performance measure would not accurately represent the need for maintenance over time for industrial lifting equipment. In the real world, the mass of the loads changes between every load and it has a significant effect on the stress the support framework and girders experience in operation. Instead, a combination of the mass times the distance moved could be a more reliable indicator of the performance of an industrial crane.

On the other hand, a performance measure more accurately depicting the performance of a maintenance contract might not have to have anything to do with the amount the asset is used, but instead with the performance of the maintenance. Therefore, the availability of the asset might be a simpler, more reliable and an overall better metric for performance measurement. For example, a contract could promise 100% asset availability with supplier penalties for any periods of unavailability. This way performance monitoring could even be largely outsourced to the client, who would be responsible for reporting any asset unavailability. However, with this performance model, the difference between an on-going preventive maintenance contract and PBC would be nothing more but the addition of penalties for asset downtime. These penalties already exist in some forms in many industries.

Significant changes in the asset's use over time also mean changes in the maintenance needs of the asset. Communicating these changes and trends to the supplier before the fact is preferable is possible. By predicting asset usage trends, the supplier can prepare, plan and allocate a more accurate amount of resources to certain PBC clients.

8.3 Asset Maintenance, Prognostics and Diagnostics

With IoT and sensor technology growing more and more affordable, remote monitoring can be a solution for many companies. Remote monitoring of assets has been proven to be beneficial for maintenance quality, research and development, and finding further sales leads for clients.

The supplier's confidence in its own service/maintenance quality is an important internal requirement and driver for PBC. PBC is a strong external sign of the supplier's trust in themselves, and thus this trust has to be present internally also. The supplier's products should have an ongoing need for maintenance as this will create a strong case for the client to choose PBC as their go-to contract model. The higher the value of maintenance has, the higher the value of PBC becomes. Remotely monitorable assets/performance also benefit

the PBC model indirectly by enabling efficient centralized condition monitoring and maintenance need predictions.

8.4 Supplier Risk

Sumo's et al. (2016) case study also shows that in order for innovation to happen in the PBC supplier's organization, even if it has all the external (relationship, contractual) prerequisites for it, the organization must not be risk-averse. A supplier that is risk-averse and does not have the expertise or processes required to manage risks comfortably, is unlikely to be able to innovate while under PBC. The main risk for the supplier in PBC comes from the fact that the asset's manufacturing costs won't be covered by the contract for a few years, meaning the contract is not expected to make any profit for those first few years. The supplier needs the capabilities of managing this risk through a thorough client selection process to ensure PBC is only offered to clients who are suitable for PBC.

A supplier who is willing to take on the risk of investment to themselves can look much more attractive to a client who is risk-averse. Not only will the risk be shifted from the client to the supplier, but it also shows the supplier's trust in their own products' quality.

8.5 Business Model Innovation

Bringing the PBC model into an organization's offering portfolio is essentially a business model innovation. Instead of innovation to improve products and processes, it brings a new way of supplier-client interaction and changes the way a service is valued and paid for. The majority of corporate senior managers and executives agree that business model innovation is the preferred source of future competitive advantage, over product and process innovation (Amit et al. 2015).

A successful business model requires checking and updating at certain intervals. Market changes, new technologies and trends can be gamechangers and business models must adjust to changes in dynamic markets. A business model is developed based on the circumstances,

environment and assumptions prevalent today. In 5 years, the environment and prevailing assumptions might have changed radically, meaning the basis on which a business model was built, is now outdated. It is important to actively study the business environment and understand what changes in it require changes in an organization's business model.

Business model innovation is a complex and cross-functional concept to manage, as a business model defines not only the financial aspect, but also plays a significant role in how the organization functions, what kind of business processes are in place, and how the customer interacts with the supplier. For example, by moving from a traditional one-time sale model into a subscription style business model, the company creates a stronger incentive for itself to focus more on retaining existing customers, encouraging improved customer service and continuous development to keep the customers interested. The ongoing relationship with subscription customers can also act as an efficient sales channel for companies.

Koen et al. (2011) describe how more established organizations that are more set in their ways than their younger counterparts generally are successful in innovation aimed at sustaining existing business. However, more radical innovation, such as introducing a new business model that modifies the existing value network is something established and traditional organizations often struggle with and frequently fail at.

Frankenbergen et al. (2013) point out that when a business model innovation attempts to restructure the value creation for a company's existing customers, the challenge of integrating that new way of doing business into the company's existing product and service portfolio can be difficult. The new business model does not have to be applied to the whole portfolio, and it does not have to be mutually exclusive with other models. Different business models can exist side by side.

A challenge in having multiple business models in a company's portfolio can lead to cannibalization of its own profits. With PBC for example, a client who has been purchasing

more traditional preventive care service packages with poor success in maintaining a high asset availability due to a difficult asset environment, might switch to a performance-based service contract, and benefit significantly from the supplier's risk exposure due to low asset availability.

8.6 Innovation Culture

Some of the main benefiters of PBC inside the supplier organization, are the innovation department and R&D. PBC increases the potential customer base of new innovation and development. In a traditional contract the product improvements and other innovations are restricted to new product sales and modernization contracts. PBC allows the supplier to skip the sales process and lets it install any improvements and upgrades it thinks will create the client more value through increased performance.

8.7 Payment

As PBC agreements' payment is based on performance, it cannot be based on it in full. A full performance-based payment would create a significant financial risk for the supplier as there would be a theoretical possibility of losing one-hundred percent of the revenue among with the costs put into logistics, operations and maintenance of an asset, in case the asset performed extremely poorly. The solution to reassigning risk exposure using PBC is not to go to the other extreme, where all risk is on the supplier. As PBC is based on mutual trust and partnerships, the payment model must reflect that.

The payment scheme should reflect a fair risk exposure for both parties, as well as encourage continuous improvement to achieve more cost-efficient performance. This will lead to increased supplier profits and lower client payments.

Sultana et al. (2012) present that a successful PBC agreement has two payment elements; a fixed fee that covers operations and maintenance on a more-or-less cost basis, and a variable fee that is based on the performance of an asset, to achieve the benefits of PBC like supplier

incentive to quality products and service. The fixed fee assures the supplier so that no matter what, they will have the resources and capabilities to perform all needed operations.

Below is a table for comparing different PBC payment scenarios with different achieved asset availabilities. The assumption for the fixed part of the fee is 50 000 Euros, and the maximum variable fee is 50 000 Euros, making the maximum profit margin 50 %. The fixed portion in this example is equal to the estimated annual maintenance costs for this specific client. Scenarios 1-5 show how the total annual fee would change with different asset performance rates. The selected rates are only an example and they are used to demonstrate how the PBC payment model works. In this specific example the fixed portion of the total fee is a constant, whereas the variable portion would have a linear correlation with the asset performance. In this example, a 100% performance is used to describe the asset running at maximum capacity day and night. Naturally, this is impossible due to shift changes, breaks, inspection, and maintenance. In the real world, the maximum performance could also increase as a result of operator training, client's supply chain optimization, asset modernization, and asset improvements by the supplier.

Table 2: PBC payment scenarios

PBC Scenario	Performance	Fixed fee	Variable fee (Profit)	Total fee	Profit margin %
1	1	50000	50000	100000	50.0%
2	0.99	50000	49500	99500	49.5%
3	0.95	50000	47500	97500	47.5%
4	0.75	50000	37500	87500	37.5%
5	0	50000	0	50000	0.0%

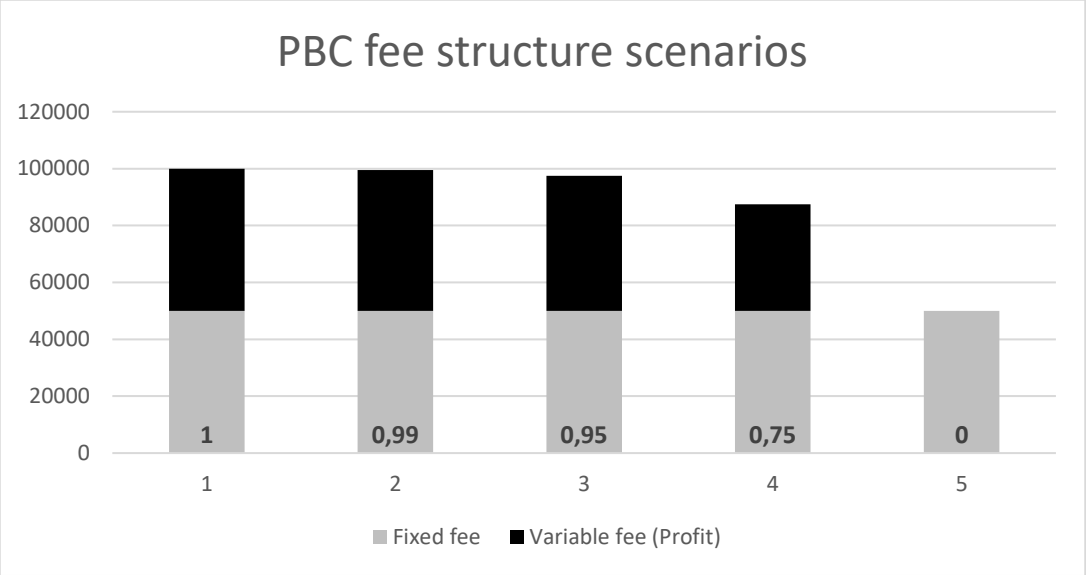

Figure 6: Stacked chart of PBC fee structure scenarios showing correspondent asset availability rates.

Scenario 1 would be the maximum profit scenario, and scenario 5 would be a situation where the operating costs of the supplier are likely covered, but no profits are gained. The figures above are only examples and serve only the purpose of demonstrating the effect of performance on payments.

8.8 Relationship

As Sumo et al. (2016) point out in their case study, a successful PBC is built on a long-term relationship with active collaboration and well-defined contract that gives the supplier autonomy in their operation. In addition to a successful contract, that said autonomy must manifest in practice, and the client should not interfere in and restrict the PBC supplier's operations and decision-making. This kind of a relationship does not come naturally to every client after a performance-based contract is signed and might require some coaching from the supplier's part. The client might have to be asked for more autonomy in case it is not granted. Sufficient autonomy is a critical factor in fostering supplier-led innovation and service improvement. The party responsible for performance must have full decision-making capability.

The willingness to establish long-term partnership is a strong driver for PBC, as it favors longer partnerships through service process innovation, existing assets' improvements and

modernization, as well as has the potential to lower costs over time and consequently lower the client's fees.

A successful performance-based contract would align the supplier's and client's goals in a way that almost anything that would provide increased value to the client, would end up increasing the income generated from the contract. For example, the supplier might offer free operator training to increase the efficient and safe use of the asset in question, increasing performance.

8.9 Renewal of Contracts

The fact that PBC is a good contract framework for long-term supplier-client partnerships, does not mean the contracts should themselves be longer than annual. As one of the benefits of PBC is the optimization of service processes and maintenance practices enabled by long-term partnerships, we can assume that the cost structure from the supplier's end will change for the better over time and maintenance can be performed in an increasingly efficient way. This creates an incentive, especially for the client, to renew PBC agreements using the new cost basis for the fixed fee part of payment, keeping the variable fee part the same, to retain the same profits. The renewal of contract brings mutual benefits to both parties when compared to the situation that was current at the time of the previous PBC agreement. The supplier is able to keep at least part of the increased profits it gained by optimizing its processes and practices, while the client is able to procure performance for a lower cost.

8.10 Product-Service Package PBC

PBC is normally seen fitting for a product-service package, meaning that the product and the related service are delivered to the client as one unit, unseparated. For an organization unfamiliar with PBC, this can be a big step to take with the uncertainty. However, supplying the asset with a PBC contract in fact seems to be a better solution than offering only PBC for maintenance. When providing the whole asset with PBC, the measurable performance would not be uptime, but instead a specific unit related to asset performance, such as hours operated, meters moved, or loads lifted. Selling an asset with PBC not only enables the same

benefits as only-maintenance PBC's but takes them further. Practically speaking, the asset wouldn't be what the client pays for, but the outcome or performance of the asset's function. This means supplier innovation and process development isn't limited to uptime-enhancing and maintenance cost effectiveness related concepts. Innovations that bring the customer increased value by increasing the performance of an asset for example through smart functionalities, IoT integration or technical improvements would be naturally incentivized for the supplier since they would lead to higher profits, whereas the customer would benefit from higher asset performance.

Asset Ownership

In a product-service package PBC (PSPPBC) the full ownership of the asset would be with the PBC supplier. This means the supplier wouldn't receive large lump-sum capital gains at the time of the asset delivery. Instead, the profits would be spread out over a longer period. Having the ownership of the asset also means the supplier is fully responsible for its functionality and performance. Since the performance would be measured in actual asset functionality related units, asset downtime or decreased performance due to poor condition or outdated technology and parts would mean direct losses in profit.

Pricing

As the asset would not be 'sold' to the client per se, the income otherwise gained from asset sales would have to be compensated for. This is especially relevant in clients with lower asset use. For example, a client who uses an asset for 200 hours a year would yield significantly lower profits than a client using the same asset year-round, day-round, for over 5000 hours a year. Compensating for this variability could be done in many different ways.

First, it is possible to include requirements or conditions to when PSPPBC can be offered to a client. By filtering away clients with low estimated asset use, the supplier can more accurately estimate a baseline income. Disqualifying clients with less than 1000 hours of asset use per year would lower the risk introduced by the lack of capital gains from asset sales.

A second option would be not to place conditions on offering PSPPBC but set a fixed baseline performance that the client will have to pay for, regardless of the performance. Once that performance limit is reached, the client will proceed to pay for the performance as normally.

These are only two of the ways to organize fair payment model. There are many different options to consider, but the underlying idea is to at least to some degree secure enough income for the supplier to continue running operations, even if the performance is sub-par. After this portion of the income, any extra should directly reflect the performance.

8.11 Example

The cashflow differences in different industrial asset sale and maintenance models can be estimated accurately enough to give an idea of the general trends. See attachments 1.1 and 1.2. The following assumptions were made when building this specific cashflow example. Assumptions 7-9 were included to allow for a *ceteris paribus* -approach to the cashflow estimate. In the real world these assumptions would not stand, and they might cancel each other out or move the profit margin one way or another.

Assumptions:

1. The asset sale price is 100 000 Euros and manufacturing cost 90 000 Euros.
2. Cost-plus model has a fixed premium of 2 000 Euros added to the yearly maintenance cost.
3. The asset has a maximum performance capacity of 2 500 hours a year.
4. Operation hours are same for each model every year.
5. The asset's average operation hours increase after year 5 significantly in this example to demonstrate how the PBC model functions.
6. PBC has an hourly fee of 15 Euros, with a minimum baseline number of operation hours of 1 000 hours, guaranteeing 15 000 Euros of income a year.
7. Asset performance does not improve through PBC enabled innovation.

8. Asset maintenance efficiency does not improve through PBC enabled innovation.
9. No costs occur from modernizing or in other ways improving the asset in subscription and PBC models.

As we can see from the table and the graph (attachments 1.1 and 1.2) both subscription and PBC models are medium-term investments from the supplier's standpoint. Where traditional asset sales with fixed fee and/or cost-plus maintenance contracts generate profit from day one due to the high capital gain coming from the asset sale, subscription and PBC models will be operating on a loss for the first 4 years. However, due to the long-term nature of both subscription and PBC models, they catch up with the more traditional models' profits in roughly a year. By year 8 we can already see a significant difference in the generated profits between the business models.

In reality, we would expect the maintenance costs from subscription and PBC models to be lower than fixed fee and especially cost-plus contracts. This is due to the supplier's autonomy and full decision-making capability of the best practices, development, upgrades, and service processes.

9. CONCLUSIONS

Performance-based contracting has been successfully implemented in multiple industries, including healthcare, the public sector (e.g. military, road maintenance), logistics and many different service industries. Some clients favor PBC agreements in order to achieve higher quality service cost-efficiently over a long-term relationship. The value of PBC is also manifested strongly in the asset's availability and performance. PBC, when implemented successfully, can bring increased profits per client for the supplier, as well as decrease overall administrative costs. Long-term relationships allow organizations to focus on and optimize processes and practices for each major client to retain their business, instead of allocating funds and resources toward acquiring new clients. New client acquisition is much more resource-spending than retaining existing business.

Not only has performance-based contracting been found to be good for both parties' bottom lines, but it can also have a liberating effect on the supplier's innovation. New product and service development is no longer restricted to new sales but can be implemented to the existing customer base where it can even further increase the existing PBC contracts' profit margins through improved operation efficacy and asset uptime. The autonomy in supplier decision making and ways of working is also desirable for the supplier to be able to deliver according to its full potential.

PBC has certain significant restrictions and limitations in the heavy machinery industry. In order for PBC to have any basis, the performance or results of an asset must be reliably measurable and quantifiable. In order for PBC to be profitable to the supplier, they must be confident in being capable of providing high quality service and maintaining a high availability for an asset. A detailed understanding of the whole environment where the asset is located is an important factor in reliable prognosis and preventive maintenance.

The major challenges for PBC in heavy machinery industry are in the significantly different payment scheme, as well as the change in risk exposure. So far traditionally, heavy

machinery suppliers have been able to allocate most of the asset-owning related risks to the client. PBC would be a paradigm change that would lead to a more balanced risk exposure and consequently lead to improved customer satisfaction and better long-term relationships. In order for PBC to work in its full potential, both parties must understand what it required for it.

In short, by linking the supplier's and client's profits directly to the performance of a heavy machinery equipment through PBC and giving the supplier with expertise a total autonomy in maintaining and improving the asset's performance, we have a system with balanced risk exposure, common interests among both parties, and increased incentives for innovation activities through low contract term specificity.

Table 3: Summary table of PBC implications

Supplier benefits	**Client benefits**
-Improved innovation capabilities for equipment, processes and service -Potential to increase income through improving performance -Able to fully take advantage of original equipment manufacturer (OEM) expertise -Shared incentives with client -Easy to sell used/refurbished equipment -Decreases required administrative tasks -More cost-effective	-Low investment risk -Simplified budget and cash flow planning -Guarantee of good performance -Shared incentives with supplier -Simplified warranty -Minimal asset downtime -Easy to exit contract if production decreases drastically -Lower mean-time-between-repairs (MTBR) -Minimal asset failures
Supplier barriers and challenges	**Client barriers and challenges**
-Unfamiliarity with PBC; what to charge? -Client might not want to grant autonomy -Ability to manage risks effectively required -Excellent maintenance expertise and know-how required -Difficult to implement in conservative industries due to resistance to change	-Unfamiliarity with PBC; How much to pay? -Supplier needs free access to asset -Difficult to implement in conservative industries due to resistance to change

In this thesis we have studied the literature related to performance-based contracting and looked at companies in different industries and how they implement or could implement PBC in their offer portfolio. This thesis proposes a framework for identifying a situation where PBC is a feasible and potentially profitable option, as well as goes to explain the major factors in successful PBC implementation.

A proposal for a future study would be to do an in-depth case study on how Rolls Royce Civil Aerospace managed their transition to PBC (internally referred to as Power by the Hour) on an organizational and managerial level. The concept of Rolls Royce's PBC model is clear, and the benefits have been thoroughly discussed, but this change to a new model will without a doubt get some resistance in most organizations due to the conservative culture in heavy machinery industries. Interviews and empirical data would be invaluable sources of data and information in understanding how this kind of a transition can be managed.

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ATTACHMENTS

Attachment 1: 10-year cashflow calculation with different payment models for asset sales and maintenance

	Year	1	2	3	4	5	6	7	8	9	10	**Total:**	**Profit:**
Fixed fee	Income	100,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	**145,000**	
	Cost	94,000	2,000	2,000	2,000	2,500	3,000	3,000	3,000	4,000	3,000	**118,500**	**26,500**
	Operation hours	720	960	1200	1440	1800	2000	2400	2500	720	2500		
	Cumulative profit	6,000	9,000	12,000	15,000	17,500	19,500	21,500	23,500	24,500	26,500		
Cost-plus	Income	100,000	4,500	4,500	4,500	5,000	5,500	5,500	5,500	6,500	5,500	**147,000**	
	Cost	94,000	2,000	2,000	2,000	2,500	3,000	3,000	3,000	4,000	3,000	**118,500**	**28,500**
	Operation hours	720	960	1200	1440	1800	2000	2400	2500	720	2500		
	Cumulative profit	6,000	8,500	11,000	13,500	16,000	18,500	21,000	23,500	26,000	28,500		
Subscription	Income	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	**220,000**	
	Cost	94,000	2,000	2,000	2,000	2,500	3,000	3,000	3,000	4,000	3,000	**118,500**	**101,500**
	Operation hours	720	960	1200	1440	1800	2000	2400	2500	720	2500		
	Cumulative profit	-72,000	-52,000	-32,000	-12,000	7,500	26,500	45,500	64,500	82,500	101,500		
PBC	Income	15,000	15,000	18,000	21,600	27,000	30,000	36,000	37,500	15,000	37,500	**252,600**	
	Cost	94,000	2,000	2,000	2,000	2,500	3,000	3,000	3,000	4,000	3,000	**118,500**	**134,100**
	Operation hours	720	960	1200	1440	1800	2000	2400	2500	720	2500		
	Cumulative profit	-79,000	-66,000	-50,000	-30,400	-5,900	21,100	54,100	88,600	99,600	134,100		

Attachment 2: Graph: 10-year cashflow calculation with different payment models for asset sales and maintenance