The Value of Embedded Technology Enabled Digital Services: A Study of Vehicular Remote Diagnostics Services

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Abstract. This research-in-progress paper shows the importance of investigating the value of the digital services that are enabled by digitalization of previously non-digital physical products or services. As the digital services are coupled with non-digital physical products, we argue that these digital services can create value in a different way and thus require more attention. We are conducting research on remote diagnostics services that are enabled by embedded technology in vehicles. With the help of layered architecture of digital technology, our initial findings show that value can be created in different ways at different layers of remote diagnostics services.

Keywords: Remote Diagnostics Services, Digital Services, Value, Digital Innovation.

1 Introduction

Many manufacturing companies are now providing services using embedded digital devices in the manufacturing products [1]. One such industry is the vehicle industry. There are research initiatives in Europe to embed digital devices inside vehicles and remotely diagnose the faults in various parts of the vehicles [2,3]. With this type of technology, a vehicle manufacturer gets the opportunity to offer innovative digital services related to vehicle maintenance to its customers. The services also reduce the possibility of breakdown of customers’ vehicles [4]. In this way, the digital services can create value both for the vehicle manufacturers and their customers.

However, digital services embedded with physical products are different from other services. Wise and Baumgartner [5] categorized these kinds of embedded digital services differently from the other services that the manufacturing companies provide in addition to their products. It has been argued that digital services create new opportunity for value creation and help a company to gain agility [6]. Moreover, Yoo et al. [7] also state, “digital technology’s transformative impact on physical products has remained surprisingly unnoticed in the IS literature (p. 725)”. Based on these arguments by Wise and Baumgartner [5], Sambamurthy et al. [6] and Yoo et al. [7], we can say that it is important to study the value aspect of digital services enabled by embedded technology in the non-digital physical products. This provides motivation for our study. The research question addressed in this paper is therefore:

What is the value of digital services that are enabled by the digitalization of non-digital physical products?
To answer this question, we investigate an empirical situation where a vehicle manufacturing company in Northern Europe is aiming to bring innovation in its vehicle maintenance services through remote diagnostics technology. In remote diagnostics technology, digital devices are embedded in the vehicles and the devices monitor and diagnose problems with various vehicle parts. This will reduce the possibility of breakdown by predicting faults in advance. With the help of this technology, the company is expecting to offer innovative digital services related to vehicle maintenance. We shall study the value aspect of these digital services.

The paper is organized as follows. First, we look at the related literature on value creation that shows connection to innovation. Later, as our study shows an example of digital innovation, we discuss layered architecture of digital technology as an important aspect of digital innovation. We conduct action research as our research method. We describe the project that is connected to this study. Then we present our initial findings. The discussion section explains the initial findings in connection to the layered architecture of digital technology.

2 Literature Review

2.1 Value Creation in Innovation

The connection between value creation and innovation has been discussed in extant literature. Porter [8] argues that with the use of new technology, firms can create value when they develop innovative ways of doing things. Innovation activities have the potential to impact value creation. Value creation is connected to the innovation of the products and services that increases customer satisfaction when the customers use the products or the services [9, 10]. Following Schumpeter [11], Amit and Zott [12] also point out to the fact that innovation is the source of value creation. Greater customer value relies on a firm’s ability to innovate [13].

While discussing about technological innovation, Teece [14] explains how technological innovation can create value for a firm. Through the protection of property rights, use of dominant design and complementary assets, a firm can gain profit from technological innovation. A firm that focuses more than the competitors on technological innovation and gain more technological capability, gets more benefit than the competitors [15, 16]. Over the past few decades, with the implementation of information technology innovation, positive impact has been observed in banking sector, chemical industry and tourism [17]. Innovation through information technology can have a real impact in customer relationship management. Firms are now providing services through state-of-the-art information technology and getting closer to the customers. One such example is the case of Apple where the customers are given opportunity to choose their favourite apps from the app store [18]. It has also been observed in the past that innovative information technology helped firms in transforming their business and changing customer relationships [19].

Looking at the previous studies that show how innovation creates value to the firms, we can see the importance of studying the value creation aspect in technological innovation. Although the previous studies show the necessity of studying value
creation through innovative information technology, little is known about the potentials of value creation when a firm is innovating through embedding digital technology in its products.

2.2 Digital Innovation

Yoo et al. [7] define digital innovation as ‘the carrying out of new combinations of digital and physical components to produce novel products (p. 725)’. A necessary combination of digital innovation is that the new combination depends on digitization, i.e., the encoding of analogue information into digital format. The most important aspect of digital innovation is the application of digital technology. Digital technology follows a layered architecture [20, 21, 22]. The layered architecture of digital technology consists of the following layers: Device layer, Network layer, application layer and contents layer [7, 23]. The following diagram shows a pictorial view of the layers.

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<table>
<thead>
<tr>
<th>Content Layer</th>
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<tbody>
<tr>
<td>Application Layer</td>
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<td>Network Layer</td>
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<td>Logical transmission</td>
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<td>Physical transportation</td>
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<td>Device Layer</td>
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<tr>
<td>Logical device OS</td>
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<td>Physical Machinery</td>
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Figure 1: Layered architecture of Digital Technology

The device layer deals with hardware and operating systems, network layer manages logical transmission and physical transport, application layer provides application functionality that directly serves users during storage, manipulation, creation and consumption of contents. The content layer contains data such as texts, images, sounds, video etc. Because of the continuous digitalization of earlier non-digital products and services, this four-layered architecture of digital technology has become more expansively applicable for all types of digitalized products. Before digitalization, these four layers were tightly coupled together with a particular product boundary and in case of some purely mechanical products such as an automotive, these layers did not exist. As a consequence of the digitalization, these four layers will be decoupled or loosely coupled to a greater extent [7].
Combing components from different layers using set of protocols can create alternative digital products which is known as combinatorial innovation [20, 24]. Due to the combinatorial innovation, different layers in digital technology can be utilized by different set of actors. For example, Apple provides opportunity to the app developers to develop new application functionalities at the application layer. It is evident that the app developers have no connection with the design of main iPhone at the device layer. The users of iPhone are choosing their favorite apps from the app store. Thus, digital innovation is creating opportunity for the users of the technology to create value both for the service providers and the receivers. Moreover, digital innovation of products and services is creating new opportunities for value creation and it is necessary to be studied [1].

3. Research Approach

3.1 Method

Action research is used for this research. Action research aims at expanding scientific knowledge through solving practical problems [25]. The reason for doing action research in this research is to develop knowledge about the value aspect of digital services. Besides contributing to the knowledge on digital services, it will help the practitioners to make a better understanding of the value aspect of the digital services for their business. There are various ways of doing action research [26] and we are conducting canonical action research because of its rigorous nature [27]. At the centre of canonical action research, there is client system infrastructure. The client-system infrastructure is the specification and agreement that constitutes the research environment. It provides the authority, or sanctions, under which the researchers and host practitioners may specify actions [26]. Canonical action research consists of five phases [26, 27]:

The first phase of canonical action research is the diagnosis phase. It corresponds to the identification of the primary problems that are the underlying causes of the practitioner’s desire for change. This diagnosis will develop certain theoretical assumptions (i.e., a working hypothesis) about the nature of the organization and its problem domain.

Researchers and practitioners then collaborate in the next activity, action planning. This activity specifies actions that should relieve or improve the primary problems. The discovery of the planned action is guided by a theoretical framework.

Action taking then implements the planned action. The researchers and practitioners collaborate in the active intervention, causing certain changes to be made.

After the actions are completed, the collaborative researchers and practitioners evaluate the outcomes.

Specifying learning denotes the on-going process of documenting and summing up the learning outcomes of the action research cycle. These learning outcomes should constitute knowledge contributions to both theory and practice, but they are also recognized as temporary understandings that serve as the starting point for a new cycle of inquiry.
3.2 Project Setting

This paper addresses an action research project jointly initiated by a bus manufacturing company SmartBus (Pseudonym) in northern Europe and researchers from a university to explore the area of remote monitoring and diagnostics of the buses. With the development of the remote diagnostics, vehicle maintenance business of SmartBus is expected to be expanded. It is also expected to help SmartBus to provide innovative services to its customers. Currently, the business of SmartBus is very much focused on selling buses. They provide some maintenance services to their customers when they sign service contracts with the customers. According to the current service contract, the company provides services to their customers’ buses in every 3 months or 6 months. The maintenance services include changing different parts, and do some other required operations so that the buses keep working. In spite of doing all these maintenance services, buses still have unexpected breakdowns. So, there is a need for the company to come up with a better idea for a more effective and efficient bus maintenance that can make it more service oriented. Remote monitoring and diagnostics seem to be a technology that can fulfil that goal to a large extent. This is the motivation behind the project. There are two aims of the project. First, to implement systems that will enable monitoring of the vehicles remotely, predict the faults in advance and diagnose the faults so that necessary steps can be taken before any breakdown occurs. There will be embedded devices with the vehicles that will predict faults and send diagnosed signal wirelessly to a remote station where technicians can be able to take next necessary decisions. Second aim of the project is to develop services out of this new technology. As the remote diagnostics technology opens the doors for providing vehicle maintenance services based on embedded digital technology, it seems important to identify and develop the services that can fulfill the customer needs. Neither SmartBus nor the technology developers themselves can identify all the customer needs. So, we find it necessary to converse not only with the people from inside the company, but also with the potential customers of these innovative digital maintenance services to gain a deep understanding so that maximum possible services can be developed with the help of the technology.

The members of this project include three informatics and three technical researchers from academia, three technology developers, two service developers and a project manager from SmartBus. The authors of this paper are among the informatics researchers who actively take part in different activities. We conducted number of various activities in order to collect data together with different participants from the vehicle industry. These activities include meetings, workshops, interviews, observations, market analysis and e-mail correspondences.

Public transport operating companies are among the customers of SmartBus. To gain customer perspectives, we conducted workshop, interviews with the traffic managers, service technicians and the drivers of three public transport operating companies.

The following table shows the participant and activities during data collection
<table>
<thead>
<tr>
<th>Activities</th>
<th>Participants (Numbers)</th>
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| Service development meetings (Biweekly and on-demand) | • Service Developers (2)  
• Project Manager (1)  
• Technical Researcher (1)  
• Informatics Researchers (3) |
| Workshops                                      | • Business Area Representative (3)  
• Informatics Researchers (3)  
• Traffic manager (1)  
• Drivers (2)  
• Service technician (1) |
| Monthly Project Meetings                       | • Service Developers (2)  
• Project Manager (1)  
• Informatics Researchers (3)  
• Technical Developers (2)  
• Technical Researchers (3) |
| Interviews                                     | • Business Area Representatives (3)  
• Maintenance Manager (1)  
• Service Developers (2)  
• Traffic managers (4)  
• Drivers (5) |
| Documents (Meeting notes, weekly Project reports, mail correspondence) | • Service Developers (2)  
• Project Manager (1)  
• Technical Researcher (1)  
• Informatics Researchers (3) |
| Market Analysis (information regarding various competitors, obtained mostly from the web contents) | Informatics Researchers |

### 3.3 Data Analysis Strategy

In the data analysis process, as data analysis materials, meeting notes from service development meetings and monthly project meetings, the transcription of interviews and workshops and the documents are used. The materials are coded using the qualitative coding types described by Richards (2009). Three types of coding such as, descriptive coding, topic coding and analytical coding and he emphasizes that all three types of coding are required for a passage of text (in an interview transcript or meeting notes). Descriptive coding allows the researcher to store the information about the speaker (in our case, for example, a traffic manager in a bus operating company). Topic coding allows to code the topic that is being discussed in the text. Topics such as, repair, cost, time, maintenance etc are used for topic coding when the texts are coded. Finally, analytic coding helps us to identify what’s going on in a passage of text, i.e., identifying several themes that are worth noting. According to Richards (2009), the analytic coding finds out categories that are not known before.
4. Initial Findings

We start our action research by investigating the existing situation on bus maintenance. The aim is to identify the problems of existing maintenance activities and the potentials for remote diagnostics. From service development meetings and monthly project meetings with the project members, we have understood that the technology developers are trying to analyse and solve the problems that they think are critical. Their identification is based on data from a previous project. We have found that it is important to discuss with a maintenance service manager in the organization. He emphasized that the current maintenance activities are not time and cost efficient. There are lot of unnecessary maintenance works even if they are not required. It happens because of the service contracts. As he states:

*We have to change engine oil and other things on a scheduled basis as per the contract. The changes are not often required but we do it. That is one of the activities of scheduled maintenance. Buses are brought to us and we do some routine checks and changes. It will save time both for us and the customers if a system can predict faults in a particular part. Their buses will be in operation until it is really important to do some maintenance works.*

Although SmartBus offers maintenance service to their customers, only 20% of their customers have signed service contracts. That makes things difficult for SmartBus to get information regarding most of the buses that they sell. A business area representative says:

*Many public transport companies have their own workshops. They do not feel the necessity of signing service contracts with us. Probably, they do not find our contracts attractive enough. We need something like remote diagnostics to make the service contracts more sellable. We have different kinds of service contracts. Remote diagnostics can be offered with one of our contracts.*

The information gained from the remote diagnostics can be helpful to develop services that the company can use to build customer relationship. They will not only be able to control the digital information but also decide what services they should provide. A service developer says during a meeting:

*The back-office can be able to see the signals coming from the buses and based on the signals we shall see the condition of the buses. Any irregularity can be informed to the bus owners so that their buses can be saved from any possible breakdown.*

There is problem with the existing technology inside the buses of SmartBus. They have a system called ‘Error codes’ they show error signals if something is wrong with the bus. However, the information from the systems is redundant and not trustworthy. A maintenance manager of SmartBus says:

*Today we have systems to display error signals in the buses. But the signals appear very frequently on the screen in front of the driver and most of the signals are negligible and the drivers often skip them. Does an error signal mean that the bus should be stopped or can it be driven anyway? How can one identify the seriousness of a problem from an error signal?*
Interview with the maintenance manager also reveals that current fault detection in the buses consume plenty of working hours. Based on the complaints from the drivers, the technicians assume the source of a problem. Then they try different things, change different parts until the problem is solved. When the problems is finally solved, it still can be difficult to identify the source of the problem as during the repair or maintenance activities lots of processes are followed and some parts are changed. The problem might exist in any of the parts or the problem has been solved during any of the work processes. The maintenance manager compared it with detective work:

*The reason for a problem sometimes is not that straightforward. Sometimes we need to do a lot of detective works. The drivers sometimes indicate to a source of a certain problem and we identify totally a different reason for that problem.*

He also mentions about the reliability issue of an existing system:

*We have system to check tyre pressure but it is not standardized and very expensive. It is not quality assured to be installed in all buses. That is why we check the tyres manually.*

Although the maintenance manager points at one or two problems regarding bus maintenance, the technology developers need to know more about the problems so that they can solve them with the help of remote diagnostics:

*The main issue here is that we need to know different types of problems that occur in the buses so that we can take initiative to solve the problems through remote diagnostics. This will create opportunity for developing different services based on this technology.*

From the discussion with the people inside SmartBus, we realize that the existing maintenance procedure is not cost and time efficient. The existing technology is not reliable. Moreover, the technology developers do not have adequate idea about what problems to address with remote diagnostics. They do not know how the technology can create value for them as well as for their customers as they have contact with very few customers after they sell the buses.

We decide to contact some of the customers of SmartBus to understand about the problems in maintenance and their thoughts and expectations from remote diagnostics systems. Before that, the technology developers discuss the remote diagnostics technology and its potentials during the monthly project meetings. It helps us to get a deep understanding about the technology and its potentials. One reason behind getting the information about the technology is to understand how it can help SmartBus in their business. Another reason is to explain it to their customers so that they can identify its value for their business. The action planning phase is guided by the layered architecture of digital technology. We plan to identify the value creation with respect to the layers.

We plan to discuss with the customers regarding bus operation and maintenance. The public transport operating companies are among the customers of SmartBus. Our plan is to involve the traffic managers, service technicians and drivers of some public transport operating companies in our activity so that we can get information about
how public transport companies operate and maintain their buses. In this way, we can identify the customer needs and inform it back to the technology developers.

We had meetings with the technology developers. They explain that the design of the main device of remote diagnostics is based on a specific algorithm and the algorithm is patented. From that point of view, the device is brand specific. Other companies are not allowed to use the algorithm. It gives a competitive advantage. A technology developer says:

_The device is only applicable for the buses manufactured by our company. It cannot be used in other brands. So, it is very much a closed system._

Our market analysis shows that some other companies also have diagnostics tools for their buses. We ask the technology developers, 'what is special about the remote diagnostics technology that you are developing?' They explain that although there are some diagnostics tools available in the market, the technology of SmartBus will differ in a certain way. One of the technology developers explains:

_Most existing diagnostics or error detection systems are not on-board diagnostics tools. There is a requirement for analysis of the error codes by some experts. We are implementing a system where the diagnostics will be done by the main device in the bus and it will send an analysed signal about the irregularity. No more expert analysis will be required._

When we start discussing with the personnel of a public transport operating company, they reveal some problems regarding few specific parts of the bus. A traffic manager says:

_We often encounter problems with the gear boxes. I don’t know whether it is common among the buses of SmartBus, but it occurs quite often._

Apart from the problems with gear box, the personnel of the public transport operating companies also discuss about the problems with doors. It seems to be annoying the drivers. One of them mentioned:

_Sometimes doors don’t get closed automatically as they normally do when the button is pressed from the driver’s panel. It can be a real headache. Drivers should not drive the bus with the doors open. It is not safe. Something should be done with the doors._

Once a contact is established between SmartBus and one of its customers (a public transport operating company), the technology developers start using some of the customer’s buses to embed the device to obtain data for analysis. It is a major step taken by SmartBus as they require real buses to do the experiments with the technology. A comment from a developer during a meeting:

_We would like to get some real data from the buses. Hopefully, the device will receive signals from various electronic control units (ECU). The initial signals that we will get will be really helpful for analysing the patterns of different parts of the buses._

Besides using the buses for experimental purposes, the developers also start looking at the service records at the operating company. This helps them to understand the
maintenance activities that have been conducted over the past few months. They get some idea about the parts of the bus that require most repair or maintenance.

Later, we conduct a workshop with the personnel of another public transport operating company. They are asked to draw futuristic scenarios with the use of remote diagnostics systems. The motive behind the activity is to understand their expectations from the technology. A traffic manager, a service technician and two drivers participated in the workshop. They find out few issues that they think can be solved by remote diagnostics. First, they refer to the door problem. They suggest an innovative solution to the door problem with the use of remote diagnostics. Second, they suggest a solution to the problem that occurs with the monitoring of ticketing system.

An interview with a traffic manager of another operating company points at few other issues. We find that fuel consumption can be monitored with the use of remote diagnostics. There is difficulty in understanding the problem patterns of the buses. Moreover, driver behaviour can also be monitored with this technology. Many other problems are also mentioned by the traffic manager. While discussing about the potential of remote diagnostics, the manager mentions:

*Based on the information obtained from remote diagnostics, it will be easier to do the route planning. If a fault is predicted before any breakdown occurs, we can plan to deploy another bus on that route.*

5. Discussion Based on Initial Findings

Our initial findings suggest that due to the patented algorithm and property rights, the digital services can create unique value for the firm that provides the services. This value creation takes place at the device layer of the layered architecture of digital services. When a digital device is designed in a way that it can only be embedded in the physical products manufactured by a specific firm, the device can create value for that firm as other firm cannot use the same device. This adds to the discussion of Teece [14] who argues that property rights create value in technological innovation. Our study shows how it creates value for digital services obtained through innovating physical products. During digital innovation, value creation can occur at the device layer through property rights. Our study also shows that with the use of embedded digital device in a physical product, the product quality can be improved. This happens when the firm gets information from the device regarding the functioning of the product. Any deficiency in the product can be reduced through a new approach in developing the product.

The firm and its potential customers can co-create services at the application layer and the content layer. In a B2B setting, as in the case with our empirical situation, the firm can co-develop and co-innovate the digital services with existing or potential customers. The application layer consists of the application functionalities. The technology developers design the applications. As we have seen from our findings, the customers can discuss their existing problems related to the product and the technology developers can address the problems when they are designing the application functionalities at the application layer. The technology developers attempt to solve the problems identified by the customers. This process can be referred to as
co-development [28]. Moreover, our findings suggest that the customers come up with innovative ideas that can be useful in the service design. This particular example can be called co-innovation. Thus, co-innovation provides the opportunity to the potential customers to co-create the digital services. This is an example of value co-creation as co-creating with customers is referred to as value co-creation [29].

As the receiver of digital services, specific value is created for the customers at the content layer. Customers own the physical products and the digital devices are embedded with the physical products. Our initial findings show that in the case of services obtained through the embedded digital technology, the customers can use the information to take decisions that can positively affect their businesses. Moreover, the embedded technology helps to improve the condition of their products.

6. Future Plan
Next plan is to look at the value aspects of the remote diagnostics services more in detail with the four layers of digital technology. Initial findings gave us some idea how value is realized in some layers. However, as we shall investigate more into it, we shall be able to find more value aspects of remote diagnostics services at the device, network, application and content layers.

References