Engineering Management in Production and Services
Volume 16 • Issue 2 • 2024

sciendo

International Society for Manufacturing, Service and Management Engineering

received: 1 August 2023
accepted: 15 March 2024

pages: 128-147

Towards a taxonomy of design options for augmented reality-based remote service business models

Stefan Ohlig
David Breitkreuz
Aliyu Aliyu
Rakesh Mishra
Dirk Stegelmeyer

Stefan Ohlig
School of Computing and Engineering, University of Huddersfield, Queensgate, Huddersfield, HD1 3DH, United Kingdom
Institut für Interdisziplinäre Technik, Frankfurt University of Applied Sciences, Nibelungenplatz 1, 60318 Frankfurt am Main, Germany
ORCID 0000-0002-9642-3010
Corresponding author:
e-mail: stefan.ohlig@hud.ac.uk

David Breitkreuz
School of Computing and Engineering, University of Huddersfield, Queensgate, Huddersfield, HD1 3DH, United Kingdom
Institut für Interdisziplinäre Technik, Frankfurt University of Applied Sciences, Nibelungenplatz 1, 60318 Frankfurt am Main, Germany
ORCID 0000-0002-2480-1094
e-mail: david.breitkreuz@hud.ac.uk

Aliyu Aliyu
School of Engineering, University of Lincoln, Brayford Pool, Lincoln LN6 7TS, United Kingdom
ORCID 0000-0002-3843-7510
e-mail: aaliyu@lincoln.ac.uk

Rakesh Mishra
School of Computing and Engineering, University of Huddersfield, Queensgate, Huddersfield, HD1 3DH, United Kingdom
ORCID 0000-0001-5992-5348
e-mail: r.mishra@hud.ac.uk

Dirk Stegelmeyer
Institut für Interdisziplinäre Technik, Frankfurt University of Applied Sciences, Nibelungenplatz 1, 60318 Frankfurt am Main, Germany
ORCID 0000-0001-7918-3732
e-mail: stegelmeyer@fb2.fra-uas.de

ABSTRACT
The aim of this paper is to develop design options for Augmented Reality (AR)-based remote service business models to support the implementation of AR technology for remote services currently taking place in the manufacturing industry. The design options were developed using a qualitative content analysis based on the results of a systematic literature review and on focus group discussions with 19 service-responsible industry experts from 12 German manufacturing companies. The application of a conceptual approach to taxonomy development resulted in a novel morphological framework with a total of 18 dimensions, each with two to six distinct characteristics representing the targeted design options of AR-based remote service business models. Since previous research on AR for remote services has largely neglected the business model perspective, this work makes a significant contribution to this scarcely explored research field by providing a systematic basis for describing and classifying such business models in terms of their design. The results provide industrial practice with the most important aspects to consider when designing AR-based remote service business models.

KEY WORDS
augmented reality, remote service, business model, taxonomy

10.2478/emj-2024-0018

Introduction

The use of augmented reality (AR) technology for industrial maintenance purposes has received growing interest in science and practice. Numerous AR applications have been identified (Dini & Mura, 2015; Nee et al., 2012; Palmarini et al., 2018), including remote maintenance services (Egger & Masood, 2020; Fernández del Amo et al., 2018; Fraga-Lamas et al., 2018) as one of the most prominent.

For some time now, the scientific community has been pointing out the advantages of using AR tech-

Ohlig, S., Breitkreuz, D., Aliyu, A., Mishra, R., & Stegelmeyer, D. (2024). Towards a taxonomy of design options for augmented reality-based remote service business models. *Engineering Management in Production and Services, 16*(2), 128-147. doi: 10.2478/emj-2024-0018

nology for remote maintenance (for example, Aschenbrenner et al., 2019; Mourtzis et al., 2017; Obermair et al., 2020; Porter & Heppelmann, 2017; Rapaccini et al., 2014). Essentially, this involves an increase in the speed of troubleshooting and a reduction in field service deployments. Accordingly, manufacturing companies increasingly intend to use AR technology to provide AR-based remote services (Hadar et al., 2017; Si2 Partners, 2018).

However, very few companies have successfully integrated AR into their business models (BMs) (Röltgen et al., 2019; van Kleef et al., 2010) and most research activities in this area tend to be related to technical issues (Breitkreuz et al., 2022; Marques et al., 2021; Röltgen et al., 2019). Thus, there is little scientifically sound knowledge on AR-based remote service BMs in terms of their classification or design. This is not only a practical problem for service managers, who are responsible for developing such BMs. The classification of objects in general is essential for other studies within the related field of research (Lambert, 2015b). Therefore, missing classification is also a problem for research into AR-based remote service business models.

The development of a taxonomy—as an empirical classification scheme—can address these problems. Taxonomies, due to their ability to structure and organize the knowledge of a specific field (Glass & Vessey, 1995), help to understand and analyze complex domains (Nickerson et al., 2013). Since BMs are abstract and complex concepts, taxonomies are often a subject of study in BM research. Their relevance and importance have been discussed and shown by numerous scholars (Groth & Christian, 2015; Lambert, 2015a). However, the literature lacks a taxonomy for AR-based remote service BMs.

Existing taxonomies in the field of AR, such as those of Marques et al. (2023) or Brockmann et al., (2013), do not take into account the BM perspective. They deal only with technological characteristics or aspects of collaborative work and have a completely different purpose, which clearly deviates from the aim of this work. A taxonomy of AR-based remote service BMs would improve the general understanding of such BMs, provide a foundation for systematic research on this topic, and support practitioners in the development, evaluation, and management of AR-based remote service BMs.

Since a taxonomy is an empirically derived classification of objects based on the totality of their observable characteristics (Baden-Fuller & Morgan, 2010; Lambert, 2015a), empirical data are essential to develop a taxonomy. However, because few companies are operating AR-based remote service BMs, empirical data are not yet available. Accordingly, this paper aims to provide a sound conceptual basis for the future empirical development of a taxonomy of AR-based remote service BMs.

One goal in developing a BM taxonomy is to develop dimensions and characteristics in which the BMs under consideration differ. In addition to differentiating the BMs, the dimensions also specify what must be considered when designing them. Therefore, this paper focuses on dimensions and characteristics that distinguish AR-based remote service BMs and can be used to design them. The research question is as follows: What dimensions and characteristics can be used to differentiate and design AR-based remote service business models?

The rest of the paper is structured as follows: The next chapter presents the theoretical background of this paper by elucidating the concept of AR-based remote services and highlighting the significance of studies on business model taxonomy. Chapter two details the methodology employed to develop the taxonomy, including the process for conducting a systematic literature review, focus group discussions, and qualitative content analysis. The dimensions and characteristics of AR-based remote service business models, developed through this approach, are showcased in the results chapter via a morphological box. The derivation of design options is illustrated through selected quotations. The contribution of focus group discussions to the development of these design options is also highlighted. To ensure the results are appropriately utilized for subsequent empirical iterations in the taxonomy development process, Chapter four discusses these results in light of certain conditions for taxonomy development. The final chapter summarizes the findings, outlines the contributions of this paper as well as the applicability of the results in both academic research and industrial practice. Additionally, it addresses the limitations of the study and proposes avenues for future research in the domain of AR-based remote service business models.

1. Theoretical background

1.1. AR-based remote services

Industrial maintenance tasks are often complex and knowledge intense (Aromaa et al., 2015), and thus they often require remote support from distant people (Porcelli et al., 2013). The use of AR technology is helpful when technicians need to obtain information on how, for example, a specific maintenance or repair task should be carried out (Palmarini et al., 2023; Porcelli et al., 2013; Rapaccini et al., 2014; Wang et al., 2021).

AR-based remote services in general are services that are provided using mobile AR devices that involve interacting with a so-called remote expert. Mobile AR devices (that is, AR smart glasses or AR-enabled smartphones or tablets) support the interaction between, for example, a technician at the customer's site and the remote expert. The integrated camera in the mobile AR device allows the expert to see what the technician sees on-site. In turn, the display of the mobile AR device allows the remote expert to display instructions in the form of virtual overlays directly in the field of vision of the technician on-site. Although AR smart glasses have the advantage of allowing the technician to work hands-free, both Marques et al. (2022) and our own experience from working with industry partners show that technicians in the field prefer smartphones or tablets to AR smart glasses. However, when AR smart glasses are used in industrial practice for remote service purposes, they are usually the RealWear HMT-1 (or its successor models).

Manufacturing companies can use AR technology for providing remote services in different business cases, such as inspection, diagnosis, and repair; training; system installation; system acceptance tests; or even application support (Müller et al., 2018). Unlike other AR applications (for example, AR-guided step-by-step instructions), AR-based remote services always involve a second person—the remote expert. AR-based remote services can therefore be seen as a specific form or subset of AR applications, with the central aspect of human collaboration being the main differentiator from other AR applications. However, although academia argues that companies need to adapt their BMs to implement AR (Gruia et al., 2020; Röltgen et al., 2019), little attention has been paid to the application of AR from a BM perspective (Grothus et al., 2021; Soh et al., 2018).

1.2. Business model taxonomies

"[…] the general idea of business models is intimately linked with notions of taxonomies and 'kinds'." (Baden-Fuller & Morgan, 2010, p. 157)

The BM is a distinct concept that is worthy of academic study and relevant in practice (Zott et al., 2011). Although the term business model has gained considerable attention in research and practice over the past decades, there is no accepted definition of the term[1]. In addition to the multitude of definitions, there are also many BM frameworks that describe BMs in terms of their dimensions[2]. However, while some of these frameworks are very generic and intended to describe any BM, they are less suitable for describing specific BMs. Therefore, studies on the classifications of specific BMs are a relevant part of BM research and often the result of BM taxonomy studies. Tab. 1 shows some examples.

Tab. 1. Examples of BM taxonomy studies

Author (Year)	Business Model
Labes et al. (2013)	Cloud business models
Hartmann et al. (2014)	Data-driven business models used by start-up firms
Haas et al. (2014)	Crowdfunding business models
Bock & Wiener (2017)	Digital business models
Eickhoff et al. (2017)	FinTech business models
Nickerson et al. (2017)	Carsharing business models
Urbinati et al. (2017)	Circular economy business models
Beinke et al. (2018)	Start-ups in the finance sector using blockchain
Weking et al. (2019)	Blockchain business models
Mengelkamp et al. (2019)	Local energy market business models
Möller et al. (2019)	Digital business models in logistic start-ups
Ertz et al. (2019)	Product lifetime extension business models
Möller et al. (2020)	Data-driven business models in logistics
Tönnissen et al. (2020)	Blockchain-based business models of start-ups
Perscheid et al. (2020)	Decentralized platform-based business models

[1] Overviews of various definitions of the term business model can be found in El Sawy & Pereira (2013), Zott et al. (2011), and Baden-Fuller & Morgan (2010).
[2] Groth & Christian (2015), Zott et al. (2011), Morris et al. (2005), and El Sawy & Pereira (2013) provide an overview of a number of different BM frameworks by several authors, with a specific examination of the dimensions of each framework.

Since it is the BM dimensions that constitute BMs (Al-Debei & Avison, 2010), the results of such BM taxonomy studies are BM-specific dimensions. Examples include destination or vehicle access in the case of carsharing BMs (Nickerson et al., 2017), blockchain sourcing or token system in the case of blockchain BMs (Weking et al., 2019), or data source or data interface in the case of data-driven BMs (Möller et al., 2020).

However, to the best of the authors' knowledge, no taxonomy studies of AR-based remote service BMs have been conducted to date. Accordingly, the specific BM dimensions that can be used to design AR-based remote service BMs are yet unknown.

2. Research methodology

To develop design options for AR-based remote service BMs, we followed the conceptual approach of taxonomy development by Nickerson et al. (2013). For data collection, we conducted a systematic literature review to identify publications on AR-based remote services from a BM perspective. We also conducted focus group discussions with 19 service-responsible industry experts from 12 German manufacturing companies on the topic of AR-based remote services BMs (Ohlig et al. 2020). From two identified publications as well as the transcripts of the focus group discussions, the targeted design options for AR-based remote service BMs were derived using a qualitative content analysis according to Mayring (2015).

2.1. Taxonomy development

In general, a taxonomy consists of several dimensions, each consisting of at least two characteristics. Therefore, one goal in developing a taxonomy is to develop the dimensions in which the object under consideration differs. There are a few other terms used for dimensions and characteristics, such as variables and values, attributes and values, or categories and capabilities (Nickerson et al., 2013). We decided to use the terms dimensions and characteristics, following the taxonomy definition of Nickerson et al. (2013, p. 340):

"A taxonomy T is a set of it n dimensions D_i (i=1, …,n) each consisting of k_i (k_i≥2) mutually exclusive and collectively exhaustive characteristics C_{ij} (j=1, …, k_i) such that each object under consideration has one and only one C_{ij} for each D_i."

According to Nickerson et al. (2013) the development of a taxonomy is an iterative process (Fig. 1). Even though it is fundamentally an empirical classification, one can follow either an empirical or conceptual approach during each iteration (Fig. 1, step 3). In

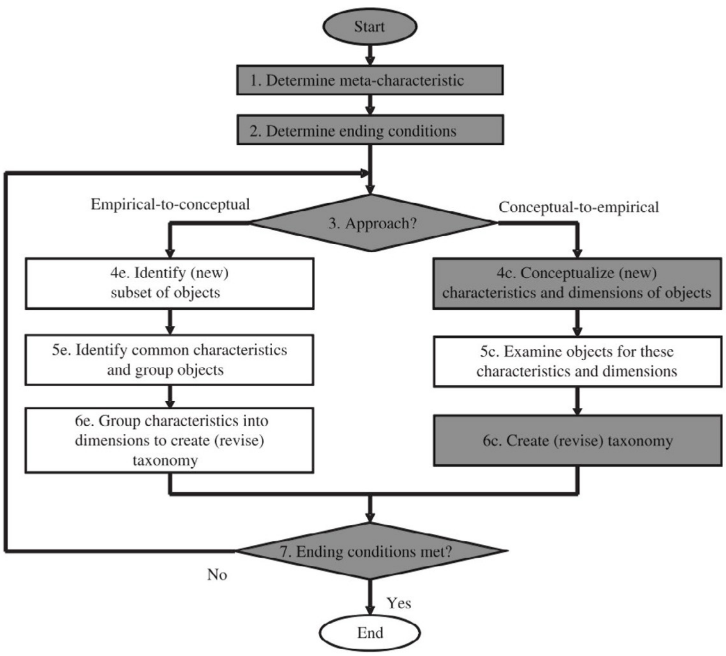

Fig. 1. Iterative taxonomy development process; gray colored elements represent the steps performed in this paper

Source: (Nickerson et al., 2013, p. 345).

each iteration, the researcher has to decide which approach to use. The choice depends on the availability of data and the researcher's knowledge about the object under investigation. Since only a few companies operate AR-based remote service BMs and thus empirical data is not yet available, we take the conceptual approach. This approach starts with the conceptualization of dimensions and characteristics (Fig. 1, step 4c), which is the first essential step towards a taxonomy when little data are available. The outcome is therefore a set of conceptually developed dimensions and characteristics, while empirical iterations will be the subject of further research to establish a final taxonomy of AR-based remote service BMs.

Regardless of the approach chosen, a meta-characteristic (Fig. 1, step 1) as well as ending conditions (Fig. 1, step 2) must be defined first. The meta-characteristic serves as the basis for the selection of characteristics in the taxonomy. That is, each characteristic should be a logical consequence of the meta-characteristic. The meta-characteristic should therefore be based on the purpose of the taxonomy (Nickerson et al. 2013). The purpose of our taxonomy is to classify AR-based remote service BMs based on their design options, which is why we define design options for AR-based remote service BMs as the meta-characteristic. All dimensions and characteristics must be a consequence of this meta-characteristic.

The ending conditions determine the point in time when no further iterations are necessary, and the taxonomy development is completed. Here we adopt the objective and subjective ending conditions proposed by Nickerson et al. (2013), which we will use later to discuss the results.

2.2. Systematic literature review

A systematic literature review was conducted with the aim of identifying publications on AR-based remote service from a BM perspective. Various terms related to augmented reality, such as mixed reality or extended reality, as well as hardware-related terms, such as smart glasses OR head mounted, were identified as key terms relevant to the topic of interest. We conducted a keyword search with these terms in combination with the term business model. To search as comprehensive as possible, we 1) used a total of eight different search engines, 2) searched for the title, abstract and keywords, 3) did not limit the search results to a specific time period, and 4) considered all types of scientific publications such as journal articles, conference papers, books and so on. The literature search is documented in Tab. 2. In total, the keyword search yielded 134 accessible full-text publications (reduced by duplicates and false entries) from all databases.

Prior to a backward and forward search, the number of publications was reduced to those relevant to the topic of interest based on an analysis of their titles, abstracts, and full texts. This was done in three sequential steps, each considering a different inclusion criterion (Tab. 3).

Step 1 aimed at identifying publications with a focus on AR (or other similar technology concepts, such as mixed reality, but no virtual reality). Some publications were excluded in this step because their focus was not on AR. Often, AR was merely listed along with other emerging technologies, such as the internet of things, digital twins, blockchain, or artificial intelligence. Consequently, the focus of these publications was mostly not on AR itself but on Industry 4.0-related technologies in general. In some other cases, the focus was on virtual reality, which is different from AR in many aspects. These publications were therefore also excluded.

Step 2 aimed at identifying publications whose focus—in addition to AR—was on the BM concept. In about half of the AR-related publications screened, the term BM was used in some way, but it was not the publication's focus. For example, it was not uncommon for the term to be used in rather general statements, for example, Industry 4.0 and its related technologies (of which AR is one) will change the BMs in the manufacturing industry.

Step 3 then aimed to identify the relevant publications for analysis that addressed AR in the specific remote service context. However, this was only the case for two publications. The first of those two was that of Niemöller et al. (2018). They investigated the impact of the use of smart glasses for remote services on the BM of a hybrid value creator and how new BMs could be created by using smart glasses. While this study provides interesting insights on the impact of AR technology use on the BM, it is based on anecdotal evidence with a limited focus on smart glasses as an AR technology.

The second publication was that of Röltgen et al. (2019). They presented a step-by-step approach for developing BMs for AR that was successfully validated by applying it to an industrial case study from a research project. While there are many established approaches for BM design in general, this approach considers specific AR-related challenges. However, the approach is general, that is, intended for multiple

Tab. 2. Search fields, filter, and number of hits per search engine/database (search conducted in September 2022)

Search Engine	Database	Search Fields	Filter	Hits
ProQuest	ABI/INFORM Collection; Publicly Available Content Database; Ebook Central	Title, Abstract	Source Type = Scholarly Journals, Working Paper, Conference paper, Books; Language = English, German	28
Scopus	-	Title, Abstract, Keyword	Language = English, German; Exclude Document type = Conference Review	120
Web of Science	Web of Science Core Collection	Title, Abstract, Keyword	No filter	38
EBSCOhost	Business Source Premier; Library, Information Science & Technology Abstracts, eBook Collection	Title, Abstract, Keyword	Language = English, German	28
Science Direct	-	Title, Abstract, Keyword	No filter	19
IEEE Explore	-	Title, Abstract, Keyword	Source Type = Conferences, Journals, Books	26
ACM Digital Library	ACM Guide to Computing Literature	Title, Abstract, Keyword	No filter	7
Google Scholar	-	Title	No filter	30
Total (only accessible full-text publications; excluding duplicates and false entries)				134
Search term: (“augmented reality” OR “extended reality” OR “mixed reality” OR “smart glasses” OR “head mounted”) AND (“business model*”)				

Tab. 3. Three-step literature screening process

Step	Step 1: Augmented Reality	Step 2: Business Models	Step 3: Remote Service
Inclusion criterion	Publications with a focus on augmented reality	Publications with a focus on business models	Publications in a specific remote service context
Included for the next step	89 of 134	48 of 89	2 of 48

and not exclusively remote service-related AR applications.

Since a backward and forward search also did not reveal any other publications relevant to the topic, only these two studies were used to derive the targeted design options.

2.3. Focus group discussions with industry experts

To derive more insightful design options of AR-based remote service BMs, we also drew on focus group discussions we conducted with service-responsible industry experts on the topic of AR-based remote service BMs. The discussions took place in January 2019 and included a total of 19 industry experts from 12 internationally operating German capital goods manufacturing companies from various industries (Ohlig et al. 2020).

Due to the focus on the service business and to ensure the validity of the results, participating industry experts were required to be strategically and/or operationally responsible for the implementation of remote AR technology in their company. However, as most companies have not yet developed an AR-based remote service BM, only those that had already tested or were currently testing AR technology for remote service purposes were selected. This ensured that the participating industry experts had a comprehensive understanding of the technical, user and customer-related aspects of remote AR technology. Thus, the assessment of expert knowledge focused on a comprehensive understanding of the impact of using remote AR technology on their company's service business rather than simply on their years of professional experience. Nevertheless, all participating industry experts had several years of professional experience in the industrial services context. Tab. 4 lists the participants of the focus group discussions.

Participants were divided into four separate focus groups and asked to discuss possible AR-based remote service BMs. Two groups discussed the case in which an AR device is used by the companies' own technician or service partner to receive remote guidance from an original equipment manufacturer (OEM) expert (case A). The other two groups discussed the case in which an AR device is used by a customer to receive remote guidance from an OEM expert (case B).

To facilitate structured discussions within the focus groups, we used the Business Model Canvas (BMC) by Osterwalder & Pigneur (2013). The BMC serves as a common language for describing, visualizing, evaluating and managing BMs. It is a widely used tool and well known among practitioners. The participants were asked to address all nine elements of the BMC and to record their results on a pinboard. The discussions were conducted in German and facilitated by a professional moderator, who had no influence on the content. Each focus group discussion lasted one hour and was audio recorded. The audio files were transcribed verbatim. Written informed consent was obtained from legally authorized representatives before the study.

Tab. 4. Focus group participants

#	Industry	OEM Information (2018)	Position of Participant within the Company	Group Nr.	Discussed Use Case
1	Bagging Systems	< 250 employees < 25 million € turnover	Head of R&D (construction)	3	Case A
			Head of Service Department	1	Case B
2	Clamping Technology for Production Technology	< 1,000 employees < 250 million € turnover	Head of Service Department (current)	2	Case B
			Head of Service Department (former)	1	Case B
			Product Manager Service	4	Case A
3	Coating Systems	< 500 employees < 250 million € turnover	Head of Service Sales & Repair	2	Case B
4	Control Valve Technology	< 5,000 employees < 1 billion € turnover	Digital Service Consultant	2	Case B
			Head of Service Support	3	Case A
5	Dry Grinding Systems	< 250 employees < 25 million € turnover	Product Manager Service	3	Case A
6	Finishing Machine Tools	< 500 employees < 100 million € turnover	Head of Service & Tool Sales	2	Case B
			Head of Electrical Assembly	3	Case A
7	Food Processing Plant Engineering	< 10,000 employees < 10 billion € turnover	Head of Customer Service	3	Case A
8	Gearing Machine Tools	< 500 employees < 100 million € turnover	Service Technician	1	Case B
			Head of Service Department	4	Case A
9	Grinding Machine Tools	< 500 employees < 100 million € turnover	Head of Service Department	4	Case A
10	Micro Milling Machine Tools	< 250 employees < 50 million € turnover	Head of Service Department	1	Case B
			Head of Service Department (deputy)	4	Case A
11	Packing Systems	< 250 employees < 25 million € turnover	Member of the Advisory Board	1	Case B
12	Vacuum Technology	< 500 employees < 250 million € turnover	Manager After Sales Service Business Development	2	Case B

Source: (Ohlig et al. 2020, p. 477).

2.4. Qualitative content analysis

In order to develop design options of AR-based remote service BMs, the two publications identified as well as the resulting transcripts of the focus group discussions were systematically analyzed following the qualitative content analysis approach of Mayring (2015). This method aims to shorten the material to be analyzed to a manageable size and to preserve the essential content. The result is a system of codes, which is an essential tool for ensuring the comprehensibility and intersubjectivity of the procedure.

To create the codes, the publications and transcripts were manually worked through line by line using NVivo software. A selection criterion that specifies which material is to be coded must first be defined. The selection criterion applied was derived from the research question and reads as follows:

Selection criterion: The text passage (single or multiple sentences) provides information about dimensions and/or characteristics that represent design options of AR-based remote service BMs.

Codes were formulated as short sentences as closely as possible to the text (that is, in-vivo-coding). Text components with little or no content, such as embellishments, repetitions, or clarifying phrases, were omitted. Text passages with relevant content were translated to a uniform language level, transformed to a grammatical short form, and translated into English if necessary. Additions by the authors that contribute to a better understanding of the respective code are placed in [brackets]. Tab. 6-23 contain examples of in-vivo-codes for each dimension and characteristic developed.

2.5. Initial business model dimensions

Groth & Christian (2015) argue that existing BM frameworks should be used when creating a BM taxonomy. Using such an overarching framework supports the derivation of the targeted BM-specific dimensions and characteristics. There seems to be a consensus here, as many authors initially draw on BM dimensions of generic BM frameworks in the development of specific BM taxonomies (for example, El Sawy & Pereira, 2013; Hartmann et al., 2014; Möller et al., 2020; Nickerson et al., 2017). This both avoids developing dimensions that are not suitable for describing BMs and ensures that relevant dimensions are not disregarded (Groth & Christian, 2015).

We also used such initial BM dimensions to guide the coding process and to develop the specific dimensions and characteristics of AR-based remote service BMs. Specifically, we used the nine BM dimensions of the BMC by Osterwalder & Pigneur (2013) as well as the BM dimension Mission of Alt & Zimmermann (2001).

3. Results

Based on a total of 199 in-vivo-codes, we developed 18 dimensions with a total of 61 characteristics that represent the targeted design options of AR-based remote service BMs. Since only about 14% of all in-vivo-codes came from the two publications analyzed (Tab. 5), most of the design options were developed on the basis of the in-vivo-codes from the focus group discussions. Thus, without the focus group discussions, we would have been able to develop only 5 of the 18 dimensions with a total of only 15 instead of 61 characteristics. This again underlines the necessity of the focus group discussions and also shows the extent to which they contributed to the development of the design options for AR-based remote service BMs described in this paper.

The dimensions with their respective characteristics are shown as a morphological box in Tab. 6 and described below. Tab. 7-24 contain examples of in-vivo-codes used to develop each dimension.

In the following and for the rest of the paper, manufacturing companies that intend to operate AR-based remote service BMs will be referred to as BM operators for short.

Type of use case: What type of use case does the BM pursue? AR-based remote service BMs can pursue different use cases (for example, remote support in troubleshooting or machine commissioning). However, instead of listing all possible use cases, this dimension distinguishes AR-based remote service BMs according to the nature of their use case, which can be differentiated as follows: Field service support: Use cases in which a field service technician is supported remotely in on-site service activities (for example, a field service technician employed by the BM operator is supported remotely in on-site troubleshooting, or a service partner's field service technician is supported remotely in commissioning a machine of the BM operator). Customer support: Use cases in which the customer's personnel are

Tab. 5. Assignment of the in-vivo-codes to the initial business model dimensions

Initial BM Dimension	Description (Reference)	Nr. of In-vivo-codes		
		Focus Groups	Literature	Total
Mission	"[…] a highlevel understanding of the overall vision, strategic goals and the value proposition including the basic product or service features." (Alt & Zimmermann, 2001, p. 7)	45	3	48
Customer segments	"[…] the different groups of people or organizations an enterprise aims to reach and serve" (Osterwalder & Pigneur, 2013, p. 20)	13	1	14
Value proposition	"[…] the bundle of products and services that create value for a specific customer segment" (Osterwalder & Pigneur, 2013, p. 22)	36	7	43
Channels	"[…] how a company communicates with and reaches its customer segments to deliver a value proposition" (Osterwalder & Pigneur, 2013, p. 26)	9	1	10
Customer relationships	"[…] the types of relationships a company establishes with specific customer segments." (Osterwalder & Pigneur, 2013, p. 28)	0	1	1
Revenue streams	"[…] the cash a company generates from each customer segment." (Osterwalder & Pigneur, 2013, p. 30)	25	2	27
Key resources	"[…] the most important assets required to make a business model work" (Osterwalder & Pigneur, 2013, p. 34)	20	5	25
Key activities	"[…] the most important things a company must do to make the business model work" (Osterwalder & Pigneur, 2013, p. 36)	7	4	11
Key partnerships	"[…] the network of suppliers and partners that make the business model work." (Osterwalder & Pigneur, 2013, p. 38)	8	2	10
Cost structure	"[…] all costs incurred to operate a business model" (Osterwalder & Pigneur, 2013, p. 40)	8	2	10
	Total	**171**	**28**	**199**

Tab. 6. Design options of AR-based remote service BMs

Dimension	Characteristics				
Type of use case[1]	Field service support[1]	Customer support[1]			
Affiliation of the AR device user[3]	Internal AR device user[1]	External AR device user[3]			
Strategic goal[3]	Cost savings[1]	Improving corporate image[1]	Improving customer relations[3]		
	Increase in new machine sales[1]	Increase in service quality[3]	Increase in service sales[3]		
Target customer group[1]	Existing service customers[1]	New service customers[1]	Third-party service providers[1]		
Customer's key value proposition[1]	Cost benefits[1]	Reduction of machine downtime[1]	Fast response[1]	Maintenance and repair know-how[1]	
Service offering[3]	24/7 remote service hours[1]	Remote connection to the machine[1]	Sale of AR devices[3]	Warranty extension[1]	
Sales channel[1]	After-sales department[1]	Specialized business unit[1]	Service technicians[1]	Helpdesk staff[1]	Training sessions[1]
AR device pricing[3]	Free of charge[1]	Free during warranty[1]	Usage fee[2]	Fixed price[1]	No AR device pricing[4]
Remote service pricing[1]	Free during warranty [1]	Pay per minute[1]	Monthly fees[1]	Technician hourly rate[1]	No remote service pricing[1]
Contractual commitment[1]	Separate contract[1]	Part of maintenance contract[1]	No contractual commitment[1]		
Type of AR device[3]	Head-worn AR device[3]	Handheld AR device[3]			
AR device connection[1]	Provided by the customer[1]	Provided by the BM operator[4]			
Remote software[1]	Commercially available software[1]	In-house software development[1]			
Remote expert skills[1]	Service technician skills[1]	Subject matter expert skills[1]			
Additional key resources[3]	3D models for AR visualizations[2]	Visual marker for AR tracking[2]	Remote connection to the machine[1]		
Additional key activities[3]	AR data preparation[3]	Smart glasses management[1]	In-house training[1]		
Key partner[3]	Remote software provider[3]	Service partner[1]	AR data supplier[2]	No key partner[1]	
Key cost driver[3]	Remote experts[1]	AR devices[3]	Remote software[1]	AR content creation[2]	

Note on the origin of the dimension/characteristic: 1 = developed exclusively on the basis of the focus group discussions; 2 = developed exclusively on the basis of the literature; 3 = developed on the basis of both; 4 = addition by the authors considering the conditions of taxonomy development (see chapter 4.1)

directly remote supported by a remote expert (for example, the customer's machine operator is remotely guided to solve a machine problem).

Affiliation of the AR device user: What is the affiliation of the person using the AR device to be supported remotely? As described in the use case examples mentioned above, different people can use the AR device to be supported remotely. Again, instead of listing all possible AR device users, this dimension distinguishes AR-based remote service BMs according to the affiliation of the person using the AR device as follows: Internal AR device user: The person using the AR device belongs to the BM operator (for example, a field service technician employed by the BM operator). External AR device user: The person using the AR device belongs to another organization outside the BM operator (for example, a technician of a service partner or a machine operator of the customer).

Strategic goal: What is the strategic goal for the operator of the BM? This dimension differentiates AR-based remote service BMs based on the strategic goal associated with the operation of the BM. The following goals, which appear to be of strategic importance, have been identified and represent the characteristics of this dimension. Cost savings: Savings, for example, in travel costs, such as unpaid travels of service technicians within the warranty period. Improving corporate image: Improvement of the corporate image through customers' increased perception of the BM operator as an innovative up-to-date company. Improving customer relations: Improvement of the customer relationship through personal and stronger customer integration. Increase in new machine sales: Increasing sales of new machines or equipment (for example, by expanding into markets not previously served due to a lack of local service infrastructure). Increase in service qual-

Tab. 7. Examples of in-vivo-codes used to develop the dimension type of use case

Characteristic	Examples of in-vivo-codes
Field service support	"We want to support our technicians when they are out [*at the customer's*], and send them drawings, for example, or provide software support." (FG3, P3)
Customer support	"It would be interesting for us to equip the customer with them [*smart glasses*] and give them support and help them more quickly." (FG3, P1)

Tab. 8. Examples of in-vivo-codes used to develop the dimension affiliation of the AR device user

Characteristic	Examples of in-vivo-codes
Internal AR device user	"My technician is at the customer's and wears the smart glasses." (FG3, P2).
External AR device user	"One can also give smart glasses to subcontractors or externals" (FG4, P2)

ity: Improvement of the service quality (for example, through improved error detection or improved service know-how of service partners). Increase in service sales: Increasing the sales of services (for example, through new revenue streams with service partners, who in turn can expand their customer base).

Target customer group: What is the target customer group of the BM? The characteristics of this dimension describe the different customer groups that the BM is designed to reach. Existing service customers: Customers who already use services provided by the BM operator. New service customers: Customers who are already part of the customer base but have not yet used services provided by the BM operator. Third-party service providers: Competing third-party service providers offering services to the installed base of the BM operator.

Customer's key value proposition: What is the customer's key value proposition? AR-based remote service BMs appear to differ in the key value proposition offered to the customer. The following characteristics representing different value propositions indicate this. Cost benefits: Cost savings compared to the previous non-remote service provision (for example, by reducing travel costs for service technicians). Reduction of machine downtime: Reduced machine downtime (for example, through AR-based remote troubleshooting of simple errors by the customer himself). Fast response: Fast response to the customer's service request (for example, through faster and improved situational awareness of the remote experts of the situation at the customer's site). Maintenance and repair know-how: Access to and acquisition of knowledge on the maintenance and repair of the machinery and equipment sold by the BM operator.

Service offering: What are the additional components of the service offer? This dimension distinguishes AR-based remote service BMs according to their service offering. The following components of the service offer represent the characteristics of this dimension: 24/7 remote service hours: The AR-based remote service is offered around the clock. Remote connection to the machine: A remote connection to the machine is part of the service offer. Sale of AR devices: The BM operator offers AR devices, such as AR smart glasses, to its customers. Warranty extension: The customer will get a warranty extension for his machines and equipment when he signs an AR-based remote service contract.

Sales channel: What channels are used to sell AR-based remote services? This dimension captures the various channels identified for selling AR-based remote services. After-sales department: Employees in the after-sales department are a sales channel. They use their contact with the customer to offer them AR-based remote services. Specialized business unit: Employees who are specialized in the sale of, for example, digital service products are a sales channel. They also use their contact with the customer to offer them AR-based remote service. Service technicians: The service technician at the customer's site serves as a sales channel (for example, by using AR smart glasses himself and describing the benefits of being supported remotely to the customer). Helpdesk staff: Helpdesk staff with direct customer contact serve as a sales channel. If they handle a service request that could be solved remotely, they offer the AR-based remote service to the customer. Training sessions: Training sessions, such as in-house training for customers or service partners, serve as a sales channel (for example, the use of AR smart glasses can be demonstrated, and the advantages of remote service explained).

AR device pricing: What does the pricing model of the AR device look like? This dimension refers to the pricing model of AR devices (for example, AR smart glasses) if they are sold to the customer. Free of charge: AR devices are provided to the customer free

Tab. 9. Examples of in-vivo-codes used to develop the dimension strategic goal

Characteristic	Examples of in-vivo-codes
Cost savings	"In this case, the business plan is not to earn additional money but only to cover costs" (FG3, P4)
Improving corporate image	"One [*the customer*] has a more positive image of the company's competences" (FG3, P4)
Improving customer relations	"The use of smart glasses can strengthen the current level of [*customer*] integration." (Niemöller et al. 2018, p. 176)
Increase in new machine sales	"The new machinery business can also go hand in hand with this." (FG1, P5)
Increase in service quality	"The quality of the partner companies [*service partners*] increases when they have the smart glasses." (FG3, P2)
Increase in service sales	"I could imagine [*that my company is*] being considered for service requests more often." (FG2, P5)

Tab. 10. Examples of in-vivo-codes used to develop the dimension target customer group

Characteristic	Examples of in-vivo-codes
Existing service customers	"Customers who already use teleservice and are familiar with the issue of being supported by external parties have been identified as potential A-customers." (FG2, P2)
New service customers	"New customers. Actually, we have supplied them with a plant. In this respect, they are not new customers. But they are new customers for service." (FG1, P1)
Third-party service providers	"Targeting third-party providers as new customers so that they in turn can expand their customer base." (FG1, P1)

Tab. 11. Examples of in-vivo-codes used to develop the dimension customer's key value proposition

Characteristic	Examples of in-vivo-codes
Cost benefits	"Cost benefits because he [*the customer*] does not have to pay for the service technician's travel." (FG2, P5)
Reduction of machine downtime	"The added value would be shortened downtimes because they [*the customers*] can help themselves more quickly." (FG2, P1)
Fast response	"Faster response time as an aspect of the value proposition." (FG4, P3); "The added value is that we have a very fast response." (FG4, P2)
Maintenance and repair know-how	"Learning by doing for the customer. Maybe he can do it [*fix the error*] himself in the future." (FG1, P3)

Tab. 12. Examples of in-vivo-codes used to develop the dimension service offering

Characteristic	Examples of in-vivo-codes
24/7 service hours	"If we have someone in the US, in Germany, and in Singapore, I have all time zones covered and I don't have to worry about 24-7." (FG3, P2)
Remote connection to the machine	"I see the connection [*to the machine*] as a basis and these smart glasses as an addition." (FG1, P5)
Sale of AR devices	"I would sell the smart glasses to the customer with the machine." (FG4, P2)
Warranty extension	"Combine a [*AR*] remote service contract with a warranty extension as an incentive." (FG1, P1)

Tab. 13. Examples of in-vivo-codes used to develop the dimension sales channel

Characteristic	Examples of in-vivo-codes
After-sales service department	"That [*sales*] has to be with after-sales, because if new equipment sales do that, it goes in as a rebate somewhere." (FG1, P5)
Specialized business unit	"For us, this [*sales*] will run through the IoT service sales channel, a special sales department that only deals with digital products." (FG2, P1)
Service technicians	"The technicians, who are at the customer's site anyway, are an indirect sales channel because they recommend this to the customer." (FG1, P5)
Help desk staff	"Our employees on the phone will ask [*the customer*] if you have a contract. If not, the contract costs 3.000 Euros and will be emailed to you."
Training sessions	"Use trainings as a sales channel and show the customer how to do it even better." (FG2, P1)

of charge. Free during warranty: AR devices are provided to the customer free of charge only during the warranty period. Usage fee: The customer pays a usage fee for the AR device provided to him for use. However, from a legal point of view, the AR device belongs to the BM operator. Fixed price: The customer buys the AR device at a certain price. No AR device pricing: There is no pricing for AR devices, as no AR devices are offered to the customer for purchase.

Remote service pricing: What does the pricing model of the AR-based remote service look like? This dimension refers to the pricing model of the AR-based remote service. The following characteristics could be identified: Free during warranty: The customer receives certain AR-based remote services free of charge during the warranty period. Pay per minute: The customer pays for the period he is supported remotely. The service is charged at a fixed price per unit of time. Monthly fees: The customer pays a monthly fee. In return, the customer receives remote support for a certain number of minutes/hours or for a certain number of calls. Technician hourly rate: The customer pays for the AR-based remote service indirectly via the service technician hourly rate (for example, increase in the technician hourly rate). No remote service pricing: There is no pricing, as no AR-based remote service is directly offered to the customer (for example, a new inexperienced field service technician employed by the BM operator is supported remotely in on-site troubleshooting).

Contractual commitment: How is the contractual commitment designed? This dimension distinguishes AR-based remote service BMs according to their contractual commitment. Separate contract: The customer can get AR-based remote services as a separate service contract, independent of a maintenance contract. Part of maintenance contract: The customer can get AR-based remote services only in conjunction with a maintenance contract. No contractual commitment: The customer can get AR-based remote services without having to contractually commit for an extended period of time.

Type of AR device: What type of AR device is used by the person who is being remotely supported? This dimension describes the different types of AR devices that can be used by the person receiving remote support. Head-worn AR device: The person being remotely supported is using a head-worn AR device, such as AR smart glasses. Handheld AR device: The person being remotely supported is using a handheld AR device, such as a smartphone or tablet.

AR device connection: Who provides the internet connection for the AR device? The AR device requires an internet connection. This dimension describes who provides that connection. Provided by the customer: The internet connection for the AR device is provided by the customer (for example, use of customer's Wi-Fi on site). Provided by the BM operator: The internet connection for the AR device is provided by the BM operator (for example, through mobile hotspots).

Remote software solution: What type of remote software solution is used? The remote software is the key software component of the BM. The following distinguishing characteristics of remote software could be identified: Commercially available software: The BM operator uses one of the numerous ready-made software solutions (with white labelling, if applicable) available on the market today. In-house software development: The BM operator develops his own remote software solution.

Remote expert skills: What kind of skills are required of the remote expert? Another key resource of the BM is remote experts. The following distinguishing characteristics could be identified with regard to their skills: Service technician skills: The remote experts are former service technicians or at least have the skills of a service technician. Subject matter expert skills: The remote experts are subject matter experts for a specific topic (for example, mechanics, electrics, commissioning, application engineering, or software).

Additional key resources: What additional resources are required to operate the BM? In addition to the actual key resources of the BM, further additional key resources were identified that could be used to differentiate AR-based remote service BMs: 3D models for AR visualizations: Construction drawings in a three-dimensional (3D) format as a basis for creating AR content for visualization purposes. Visual marker for AR tracking: Visual markers (for example, QR code stickers on the machine or equipment) to align AR visualizations relative to specific machine components. Remote connection to the machine: Remote connection to the machine control (for example, to detect or correct software errors remotely).

Additional key activities: What additional activities play a key role in the BM? Besides the actual key activity—remote support of the AR device user by a remote expert—the following additional activities could be identified: AR data preparation: Activities to prepare and create AR content that is used for visu-

Tab. 14. Examples of in-vivo-codes used to develop the dimension AR device pricing

Characteristic	Examples of in-vivo-codes
Free of charge	"The hardware [*the smart glasses*] would be provided free of charge." (FG1, P5)
Free during warranty	"During the warranty period you [*the customer*] get the smart glasses free of charge, outside the warranty period it [*the smart glasses*] costs something." (FG4, P4)
Usage fee	"Providing AR devices for a monthly usage fee." (Röltgen et al. 2019, p.634)
No AR device pricing	*Addition by the authors considering the condition of collective exhaustiveness*

Tab. 15. Examples of in-vivo-codes used to develop the dimension remote service pricing

Characteristic	Examples of in-vivo-codes
Free during warranty	"During the warranty it is free of charge." (FG2, P4)
Pay per minute	"As a source of revenue, one can do pay-per-minute, i.e., charge according to performance." (FG2, P1)
Monthly fees	"We can offer a technician on site with these smart glasses for a fixed monthly amount and thus guarantee all the know-how from the factory." (FG4, P2)
Technician hourly rate	"No longer charge a service locksmith, but a service expert for x euros instead of much less before." (FG3, P2)
No pricing	"I do not see a revenue source in this case." (FG3, P3)

Tab. 16. Examples of in-vivo-codes used to develop the dimension contractual commitment

Characteristic	Examples of in-vivo-codes
Separate contract	"We have a so-called flat rate, which he [*the customer*] can buy in separate form as an annual contract with an hourly package." (FG2, P2)
Part of maintenance contract	"Or we have it [*AR remote services*] included in maintenance contracts." (FG2, P2)
No contractual commitment	"The customer is not bound by a contract, so only incurs costs if he uses our services." (FG1, P2)

Tab. 17. Examples of in-vivo-codes used to develop the dimension type of AR device

Characteristic	Examples of in-vivo-codes
Head-worn AR device	"Smart glasses are necessary for customers to enable AR visualizations; however, most customers lack them." (Röltgen et al. 2019, pp. 633-634)
Handheld AR device	"Instead of using smart glasses, it can also be done with a smartphone." (FG1, P2)

Tab. 18. Examples of in-vivo-codes used to develop the dimension AR device connection

Characteristic	Examples of in-vivo-codes
Provided by the customer	"We need internet access, which the customer must provide." (FG2, P2)
Provided by the BM operator	*Addition by the authors considering the condition of at least two characteristics per dimension*

Tab. 19. Examples of in-vivo-codes used to develop the dimension remote software solution

Characteristic	Examples of in-vivo-codes
Commercially available software	"You certainly buy the software at the beginning." (FG2, P4)
In-house software development	"You can also do it [*the software development*] yourself." (FG3, P4)

Tab. 20. Examples of in-vivo-codes used to develop the dimension remote expert skills

Characteristic	Examples of in-vivo-codes
Service technician skills	"You need former service technicians." (FG3, P2)
Subject matter expert skills	"For us, that means five people. Mechanic, electrician, commissioning engineer, application engineer and software." (FG4, P2)

Tab. 21. Examples of in-vivo-codes used to develop the dimension additional resources

Characteristic	Examples of in-vivo-codes
3D models for AR visualizations	"AR use cases usually require 3D models specially prepared for visualization by AR." (Röltgen et al. 2019, p. 642)
Visual marker for AR tracking	"It might be necessary to add new components to the product such as visual marker for tracking." (Röltgen et al. 2019, p. 633)
Remote connection to the machine	"It must still be possible to look into the control system via a connection to the Programmable Logic Controller." (FG1, P5)

Tab. 22. Examples of in-vivo-codes used to develop the dimension additional activities

Characteristic	Examples of in-vivo-codes
AR data preparation	"Considerable effort is required to prepare the data for transmission via smart glasses." (FG2, P5)
Smart glasses management	"Deliveries and repairs of smart glasses must also be managed." (FG2, P4)
In-house training	"In-house training is a required activity." (FG4, P2)

Tab. 23. Examples of in-vivo-codes used to develop the dimension key partner

Characteristic	Examples of in-vivo-codes
Remote software provider	"With the partners, I see the software producer, depending on whether I make the app [*AR remote service app*] myself or buy it." (FG3, P2)
Service partner	"I would consider external service technicians or service companies, who then stand between the customer and us as partners." (FG1, P3)
AR data supplier	"3D models are often held by the supplier." (Röltgen et al. 2019, p. 642)
No key partner	"I have not written anything down for partners." (FG1, P5)

Tab. 24. Examples of in-vivo-codes used to develop the dimension key cost driver

Characteristic	Examples of in-vivo-codes
Remote experts	"I have also added employees [*remote experts*] as a cost structure." (FG1, P3)
AR devices	"Costs for procurement and maintenance of the smart glasses." (Niemöller et al. 2018, p. 179)
Remote software	"We pay the fees [*remote software license fees*] even if the customer does not use it." (FG1, P5)
AR content creation	"Costs for AR content creation." (Niemöller et al. 2018, p. 179)

alization purposes. Smart glasses management: Activities related to the management of AR smart glasses, such as replacement deliveries in the event of defects or firmware updates. In-house training: In-house training on the use of the AR smart glasses and the remote software.

Key partner: Which partner plays a key role in the BM? This dimension captures various key partners that make the BM work. Remote software provider: Manufacturer of the remote software, which is the main software component of the BM. Service partner: Cooperating service companies or independent service technicians who perform services on behalf of the BM operators at its installed base while being supported remotely. AR data supplier: Suppliers of data, such as 3D models, that are necessary to generate AR content for visualization purposes. No key partner: No partner is required to operate the BM.

Key cost driver: What is the key cost driver of the BM? In the case of AR-based remote service BMs, the following cost drivers were identified that represent the characteristics of this dimension: Remote experts: Personnel and workplace costs for the remote experts. AR devices: Costs for AR devices, such as AR smart glasses, especially if the BM operator's own technicians are equipped with them. Remote software: Acquisition or development as well as operation and maintenance costs for the remote software. AR content creation: Costs incurred to generate AR content for visualization purposes.

4. Discussion

Although we have explicitly not developed a final taxonomy here–which would have required empirical data–the results are discussed in terms of the conditions for taxonomy development proposed by Nickerson et al. (2013). This ensures a better understanding

Tab. 25. Assessment of taxonomy-related conditions for the conceptually developed dimensions and characteristics

Taxonomy-related conditions		Assessment
Conditions derived from taxonomy definition	At least two characteristics	Fulfilled
	Mutual exclusiveness	Considered but not verifiable (empirical data required)
	Collective exhaustiveness	Considered but not verifiable (empirical data required)
Subjective ending conditions	Explanatory	Fulfilled
	Concise and robust	Not considered
	Comprehensive	Considered but not verifiable (empirical data required)
	Extendable	Fulfilled
Objective ending conditions	All or a representative sample of objects have been examined	Not verifiable (empirical data required)
	At least one object is classified under every characteristic of every dimension	Not verifiable (empirical data required)
	No object was merged/split in the last iteration	Not verifiable without iterations
	No new dimension/characteristic was added/merged/split in the last iteration	Not verifiable without iterations
	Every dimension/characteristic is unique and not repeated	Fulfilled

Source: (Nickerson et al., 2013, p. 344).

of the results and ensures a proper use for the subsequent empirical iterations in the taxonomy development process.

However, some of the conditions cannot be verified because they must be viewed from the perspective of an empirically and iteratively developed taxonomy. Even though these conditions are marked as "not verifiable" (Tab. 25), they have still been considered at this conceptual stage of taxonomy development.

4.1. Conditions derived from taxonomy definition

At least two characteristics per dimension: This condition results from the taxonomy definition. According to this, each dimension should comprise at least two characteristics. For the dimension AR device connection, however, only the characteristic Provided by the customer could be derived from the data (Tab. 18). However, in order to fulfill the condition of at least two characteristics per dimension, the dimension was supplemented in this case by the characteristic Provided by the BM operator.

Mutual exclusiveness and collective exhaustiveness: Two further conditions, also derived from the taxonomy definition, are that the characteristics in each dimension must be mutually exclusive and collectively exhaustive. In other words, each BM must have one of the characteristics in each dimension and no BM can have two different characteristics in a dimension. To consider the collective exhaustiveness condition, we added the characteristic No AR device pricing to the dimension AR device pricing (Tab. 14) because according to the dimension Service offering, the sale of AR devices is only one possible characteristic of AR-based remote service BMs. Thus, BMs that do not involve the sale of AR devices do not require any AR device pricing. While these conditions can be considered in the conceptualization of the dimensions, since no real BMs were studied, the conditions are not verifiable. Therefore, no claim is made for mutual exclusivity or collective exhaustiveness of the dimensions.

4.2. Subjective ending conditions

Explanatory: Dimensions and characteristics should provide useful explanations, rather than only descriptions of every detail of the objects. Without taking this condition into account, some dimensions would have much more characteristics, but without explaining the objects' nature. For example, dimension AR device user could have been developed with the characteristics own service technician, third-party service provider's service technician, sub-contractor's service technician, and customer's staff. Instead, considering the explanatory condition, the dimension Affiliation of AR device user was developed with the characteristics Internal AR device user and External AR device user, expressing the AR device user's affiliation as the nature of these objects.

Concise and robust: These two subjective ending conditions refer to the number of dimensions and characteristics. It should not be too large, making the final taxonomy difficult to understand and apply, and simultaneously, the number of dimensions should not be too small to be able to differentiate among the BMs adequately. However, an ideal number of dimensions was not sought. Instead, each dimension representing design options of AR-based remote service BMs was included.

Comprehensive: A useful taxonomy should be able to classify all known objects within the domain under consideration. We addressed this condition by using initial BM dimensions from established BM frameworks in the coding process. This ensured that no relevant dimension was disregarded and only dimensions useful for describing BM were developed. Nevertheless, this condition is not verifiable as no real AR-based remote service BMs were investigated.

Extendable: This condition refers to a taxonomy's ability to include further dimensions and characteristics easily when new objects appear. The results can be considered extensible, as other dimensions and characteristics can be easily added, which of course could be the result of further empirical investigation.

4.3. Objective ending conditions

With one exception, the objective ending conditions cannot be evaluated at this conceptual stage of taxonomy development. To satisfy these conditions, the taxonomy would need to be developed in iterative steps based on real AR-based remote service BMs. Therefore, the results only fulfill the last of these objective ending conditions, namely that each dimension/characteristic is unique and not repeated.

5. Conclusion

Based on the aim of this paper–to develop design options for AR-based remote service BMs–we developed a novel morphological framework with a total of 18 dimensions and 61 characteristics that represent the targeted design options of AR-based remote service BMs. To this end, we followed a conceptual approach to taxonomy development. We chose this conceptual approach because very few companies currently operate an AR-based remote service BM and thus no empirical data is yet available.

The results were derived using qualitative content analysis from two sources. First, from the only two existing publications on the topic of AR-remote service BMs which were the result of a systematic literature search. And second, from transcripts of focus group discussions conducted with 19 service-responsible industry experts from 12 German manufacturing companies. However, most of the design options were developed solely on the basis of the focus group discussions.

Depicted in the form of a morphological box, the BM dimensions and their respective characteristics provide a novel framework that addresses the lack of a structured framework for classifying AR-based remote service BMs in the literature. In contrast to existing AR taxonomies, whether in the broader field of AR (for example, Hugues et al., 2011) or in collaborative AR specifically (for example, Brockmann et al., 2013; Marques et al., 2021), our approach includes the largely unexplored BM perspective for the first time. We also address the demand for methodological support for the design of AR-based BMs (Röltgen et al., 2019), as the dimensions and characteristics described in the framework enable the systematic description, differentiation, and design of AR-based remote service BMs.

With regard to the development of AR-based remote service BMs in industrial practice, companies will benefit from using the framework developed in this paper. It serves as a guide for identifying key aspects of AR-based remote service BMs and provides a selection of different design options. It can also be used to compare their own AR-based remote service BMs with those of other companies and identify similarities and differences between them.

It should be noted that the BM dimensions and their respective characteristics were developed on a solid, but merely conceptual basis, as both the literature and the focus group discussions describe scenarios of possible future BMs rather than real existing ones. Hence, the results need to be validated by further empirical studies.

Nevertheless, the present work represents an essential step towards the systematic description and classification of AR-based remote service BMs in terms of their design options and the creation of a taxonomy of such BMs. Further empirical studies, such as the survey of configurations of AR-based remote service BMs, should be conducted along the dimensions conceptually developed here.

In addition to empirical validation, future work could explore the identification of business model archetypes through cluster analysis. Moreover, individual dimensions of these business models could further be investigated. For example, research could delve into which pricing models for AR-based remote services are most effective and identify the underlying reasons for their success. Further studies could aim to evaluate AR-based remote service business models, focusing on economic aspects such as the comparison of costs on the one hand and profits or cost savings due to AR-based remote service on the other.

In any case, the framework developed in this paper will serve a systematic foundation for future research into AR-based remote service business models.

Literature

Al-Debei, M. M., & Avison, D. (2010). Developing a unified framework of the business model concept. *European Journal of Information Systems*, *19*(3), 359-376. doi: 10.1057/ejis.2010.21

Alt, R., & Zimmermann, H.-D. (2001). Introduction to Special Section - Business Models. *Electronic Markets*, *11*(1), 3-9. doi: 10.1080/713765630

Aromaa, S., Väätänen, A., Aaltonen, I., & Heimonen, T. (2015). A model for gathering and sharing knowledge in maintenance work. *Proceedings of the 33rd Annual Conference of the European Association of Cognitive Ergonomics*, Warsaw, Poland, 1-3 July, 1-8.

Aschenbrenner, D., Leutert, F., Çençen, A., Verlinden, J., Schilling, K., Latoschik, M., & Lukosch, S. (2019). Comparing human factors for augmented reality supported single-user and collaborative repair operations of industrial robots. *Frontiers Robotics AI*, *6*(37). doi: 10.3389/frobt.2019.00037

Baden-Fuller, C., & Morgan, M. S. (2010). Business Models as Models. *Long Range Planning*, *43*(2-3), 156-171. doi: 10.1016/j.lrp.2010.02.005

Beinke, J. H., Teuteberg, F., & Ngoc, D. N. (2018). Towards a Business Model Taxonomy of Startups in the Finance Sector using Blockchain. *Proceedings of the 39th International Conference on Information Systems - Bridging the Internet of People, Data, and Things, ICIC 2018*, San Francisco, CA, USA, December 13-16, Association for Information Systems.

Bock, M., & Wiener, M. (2017). Towards a Taxonomy of Digital Buisness Models - Conceptual Dimensions and Empirical Illustrations. *Proceedings of the 38th International Conference on Information Systems, International Conference on Information Systems (ICIS)*, South Korea.

Breitkreuz, D., Müller, M., Stegelmeyer, D., & Mishra, R. (2022). Augmented Reality Remote Maintenance in Industry: A Systematic Literature Review. *Lecture Notes in Computer Science (LNCS), 1st International Conference on eXtended Reality (XR SALENTO 2022)*, Salento, Italy, July 6-8. Cham: Springer, 287-304. doi: 10.1007/978-3-031-15553-6

Brockmann, T., Krueger, N., Stieglitz, S., & Bohlsen, I. (2013). A framework for collaborative augmented reality applications. *Proceedings of the Nineteenth Americas Conference on Information Systems*, Chicago, Illinois, August 14-17.

Dini, G., & Mura, M. D. (2015). Application of Augmented Reality Techniques in Through-life Engineering Services. *Procedia CIRP*, *38*, 14-23. doi: 10.1016/j.procir.2015.07.044

Egger, J., & Masood, T. (2020). Augmented reality in support of intelligent manufacturing – A systematic literature review. *Computers & Industrial Engineering*, *140*, 106195. doi: 10.1016/j.cie.2019.106195

Eickhoff, M., Muntermann, J., & Weinrich, T. (2017). What do FinTechs actually do? A Taxonomy of FinTech Business Models. *Proceedings of the 38th International Conference on Information Systems, International Conference on Information Systems (ICIS)*, South Korea.

El Sawy, O. A., & Pereira, F. (2013). VISOR: A Unified Framework for Business Modeling in the Evolving Digital Space. *Business Modelling in the Dynamic Digital Space*. Heidelberg, New York, Dordrecht, London: Springer.

Ertz, M., Leblanc-Proulx, S., Sarigöllü, E., & Morin, V. (2019). Made to break? A taxonomy of business models on product lifetime extension. *Journal of Cleaner Production*, *234*, 867-880. doi: 10.1016/j.jclepro.2019.06.264

Fernández del Amo, I., Erkoyuncu, J.A., Roy, R., Palmarini, R., & Onoufriou, D. (2018). A systematic review of Augmented Reality content-related techniques for knowledge transfer in maintenance applications. *Computers in Industry*, *103*, 47-71. doi: 10.1016/j.compind.2018.08.007

Fraga-Lamas, P., Fernandez-Carames, T. M., Blanco-Novoa, O., & Vilar-Montesinos, M. A. (2018). A Review on Industrial Augmented Reality Systems for the Industry 4.0 Shipyard. *IEEE Access*, *6*, 13358-13375. doi: 10.1109/ACCESS.2018.2808326

Glass, R. L., & Vessey, I. (1995). Contemporary application-domain taxonomies. *IEEE Software*, *12*(4), 63-76. doi: 10.1109/52.391837

Groth, P., & Christian, N. (2015). Constructing a Business Model Taxonomy: Using statistical tools to generate a valid and reliable business model taxonomy. *Journal of Business Models*, *3*(1), 4-21. doi: 10.5278/ojs.jbm.v3i1.1211

Grothus, A., Thesing, T., & Feldmann, C. (2021). *Digitale Geschäftsmodell-Innovation mit Augmented Reality und Virtual Reality: Erfolgreich für die Industrie entwickeln und umsetzen*. Berlin, Germany: Springer Gabler.

Gruia, L.-A., Bibu, N., Nastase, M., Roja, A., & Cristache, N. (2020). Approaches to Digitalization within Organizations. *Review of International Comparative Management*, *21*(3), 287-297. doi: 10.24818/RMCI.2020.3.287

Haas, P., Blohm, I., & Leimeister, J. M. (2014). An Empirical Taxonomy of Crowdfunding Intermediaries. *Proceedings of the 35th International Conference on Infor-*

mation Systems - Building a Better World through Information Systems, ICIS 2014, Auckland, New Zealand, December 14-17: Association for Information Systems.

Hadar, E., Shtok, J., Cohen, B., Tzur, Y., Karlinsky, L., Franch X., Wieringa R., Ralyte J., Matulevicius R., & Salinesi C. (2017). Hybrid remote expert – An emerging pattern of industrial remote support. *CEUR Workshop Proceedings*, *1848*.

Hartmann, P. M., Zaki, M., Feldmann, N., & Neely, A. (2014). *Big Data for Big Business? A Taxonomy of Data-driven Business Models used by Start-up Firms: Working paper*.

Hugues, O., Fuchs, P., & Nannipieri, O. (2011). New Augmented Reality Taxonomy: Technologies and Features of Augmented Environment. In: B. Furht (Ed.), *Handbook of Augmented Reality* (pp. 47–63). New York: Springer.

Labes, S., Erek, K., & Zarnekow, R. (2013). Common Patterns of Cloud Business Models. *Proceedings of the Nineteenth Americas Conference on Information Systems, Nineteenth Americas Conference on Information Systems*, Chicago, Illinois, August 15-17.

Lambert, S. (2015). *Do we Need a "Real" Taxonomy of e-Business Models?*

Lambert, S. (2015). The Importance of Classification to Business Model Research. *Journal of Business Models*, *3*(1), 49-61. doi: 10.5278/OJS.JBM.V3I1.1045

Marques, B., Ferreira, C., Silva, S., Dias, P., & Santos Sousa, B. (2023). Is social presence (alone) a general predictor for good remote collaboration? comparing video and augmented reality guidance in maintenance procedures. *Virtual Reality*. doi: 10.1007/s10055-023-00770-7

Marques, B., Silva, S. S., Alves, J., Araujo, T., Dias, P. M., & Sousa Santos, B. (2021). A Conceptual Model and Taxonomy for Collaborative Augmented Reality. *IEEE Transactions on Visualization and Computer Graphics*, *28*(12), 5113-5133. doi: 10.1109/TVCG.2021.3101545

Marques, B., Silva, S., Alves, J., Rocha, A., Dias, P., & Santos, B. S. (2022). Remote collaboration in maintenance contexts using augmented reality: insights from a participatory process. *International Journal on Interactive Design and Manufacturing*, *16*(1), 419-438. doi: 10.1007/s12008-021-00798-6

Mayring, P. (2015). *Qualitative Inhaltsanalyse: Grundlagen und Techniken*. 12th edn. Weinheim: Beltz.

Mengelkamp, E., Schlund, D., & Weinhardt, C. (2019). Development and real-world application of a taxonomy for business models in local energy markets. *Applied Energy*, *256*, 113913. doi: 10.1016/j.apenergy.2019.113913

Möller, F., Bauhaus, H., Hoffmann, C., Niess, C., & Otto, B. (2019). Archetypes of digital business models in logistics start-ups. *Proceedings of the 27th European Conference on Information Systems, European Conference on Information Systems*, Stockholm & Uppsala, Schweden, June 8-14.

Möller, F., Stachon, M., Hoffmann, C., Bauhaus, H., & Otto, B. (2020). Data-driven Business Models in Logistics: A Taxonomy of Optimization and Visibility Services. *Proceedings of the 53rd Hawaii International Conference on System Sciences*. doi: 10.24251/HICSS.2020.661

Morris, M., Schindehutte, M., & Allen, J. (2005). The entrepreneur's business model: Toward a unified perspective. *Journal of Business Research*, *58*(6), 726-735. doi: 10.1016/j.jbusres.2003.11.001

Mourtzis, D., Zogopoulos, V., & Vlachou, E. (2017). Augmented Reality Application to Support Remote Maintenance as a Service in the Robotics Industry. *Procedia CIRP*, *63*, 46-51. doi: 10.1016/j.procir.2017.03.154

Müller, M., Stegelmeyer, D., & Mishra, R. (2018). Investigations on augmented reality based maintenance practices within SMEs. *Proceedings of the 31st International Congress and Exhibition on Condition Monitoring and Diagnostic Engineering Management: COMADEM 2018, 31st International Congress and Exhibition on Condition Monitoring and Diagnostic Engineering Management*, Sun City, Rustenburg, South Africa, 2-5 July 2018. North-West University, 173-180.

Nee, A., Ong, S. K., Chryssolouris, G., & Mourtzis, D. (2012). Augmented reality applications in design and manufacturing. *CIRP Annals - Manufacturing Technology*, *61*(2), 657-679. doi: 10.1016/j.cirp.2012.05.010

Nickerson, R. C., Remane, G., Hanelt, A., Tesch, J. F., & Kolbe, L. M. (2017). Design Options for Carsharing Business Models. In: H. Proff & T. M. Fojcik (Eds.), *Innovative Produkte und Dienstleistungen in der Mobilität [Innovative products and services in mobility]: Technische und betriebswirtschaftliche Aspekte* (pp. 347–362). Wiesbaden: Springer Fachmedien Wiesbaden.

Nickerson, R. C., Varshney, U., & Muntermann, J. (2013). A method for taxonomy development and its application in information systems. *European Journal of Information Systems*, *22*(3), 336-359. doi: 10.1057/ejis.2012.26

Niemöller, C., Schomaker, T., & Thomas, O. (2018). Einsatz von Smart Glasses in Unternehmen – Analyse und Gestaltung von Geschäftsmodellen. In: O. Thomas, D. Metzger, & H. Niegemann (Eds.), *Digitalisierung in der Aus- und Weiterbildung: Virtual und Augmented Reality für Industrie 4.0* (pp. 170–181). Berlin, Heidelberg: Springer Berlin Heidelberg.

Obermair, F., Althaler, J., Seiler, U., Zeilinger, P., Lechner, A., Pfaffeneder, L., Richter, M., & Wolfartsberger, J. (2020). Maintenance with Augmented Reality Remote Support in Comparison to Paper-Based Instructions: Experiment and Analysis. *2020 IEEE 7th International Conference on Industrial Engineering and Applications, ICIEA 2020* (942-947). doi: 10.1109/ICIEA49774.2020.9102078

Ohlig, S., Stegelmeyer, D., Mishra, R., & Müller, M. (2020). Exploring the Impacts of Using Mobile Collaborative Augmented Reality on the Field Service Business Model of Capital Goods Manufacturing Companies. In: A. Ball, L. Gelman & B. K. N. Rao (Eds.), *Advances in Asset Management and Condition Monitoring. Smart Innovation, Systems and Technologies* (pp. 473–484). Cham: Springer International Publishing.

Osterwalder, A., & Pigneur, Y. (2013). *Business model generation: A handbook for visionaries, game changers, and challengers*. New York: Wiley&Sons.

Palmarini, R., del Amo, I. F., Ariansyah, D., Erkoyuncu, J. A., & Roy, R. (2023). Augmented Reality for Remote Assistance (ARRA). In: A. Y. C. Nee & S. K. Ong

(Eds.), *Springer Handbook of Augmented Reality.* (Springer Handbooks) (pp. 669–685). Cham: Springer International Publishing; Imprint Springer.

Palmarini, R., Erkoyuncu, J. A., Roy, R., & Torabmostaedi, H. (2018). A systematic review of augmented reality applications in maintenance. *Robotics and Computer-Integrated Manufacturing*, *49*, 215-228.

Perscheid, G., Ostern, N., & Moormann, J. (2020). Towards a taxonomy of decentralized platform-based business models. *Proceedings of the 28th European Conference on Information Systems (ECIS), Twenty-Eigth European Conference on Information Systems (ECIS2020)*, Marrakech, Morocco, June 15-17.

Porcelli, I., Rapaccini, M., Espíndola, D. B., & Pereira, C. E. (2013). Innovating Product-Service Systems Through Augmented Reality: a Selection Model. In: Y. Shimomura & K. Kimita (Eds.), *The Philosopher's Stone for Sustainability* (pp. 137–142). Berlin, Heidelberg: Springer Berlin Heidelberg.

Porter, M. E., & Heppelmann, J. E. (2017). Why Every Organization Needs an Augmented Reality Strategy. *Harvard Business Review*, *95*(6), 46-57.

Rapaccini, M., Porcelli, I., Espíndola, D. B., & Pereira, C. E. (2014). Evaluating the use of mobile collaborative augmented reality within field service networks: the case of Océ Italia – Canon Group. *Production & Manufacturing Research*, *2*(1), 738. doi: 10.1080/21693277.2014.943430

Röltgen, D., Wortmann, F., Grote, E.-M., & Dumitrescu, R. (2019). Designing Business Models for Augmented Reality. *Proceedings of the 28th International Conference for the International Association of Management of Technology (IAMOT)*, 630-646.

Si2 Partners. (2018). *Augmented Reality in Service: Ready for Prime Time? Management Report 2018*. Retrieved from https://si2partners.com/augmented-reality-service-ready-prime-time/

Soh, L., Burke, J., & Zhang, L. (2018). Supporting augmented reality: Looking beyond performance. *VR/AR Network 2018 – Proceedings of the 2018 Morning Workshop on Virtual Reality and Augmented Reality Network, Part of SIGCOMM 2018, 2nd ACM SIGCOMM Workshop on Virtual Reality and Augmented Reality Network*, Budapest, 24. August, 7-12. doi: 10.1145/3229625.3229627

Tönnissen, S., Beinke, J. H., & Teuteberg, F. (2020). Understanding token-based ecosystems – a taxonomy of blockchain-based business models of start-ups. *Electronic Markets*, *30*, 307-323. doi: 10.1007/s12525-020-00396-6

Urbinati, A., Chiaroni, D., & Chiesa, V. (2017). Towards a new taxonomy of circular economy business models. *Journal of Cleaner Production*, *168*, 487-498. doi: 10.1016/j.jclepro.2017.09.047

van Kleef, N., Noltes, J., & van der Spoel, S. (2010). *Success factors for augmented reality business models.* University of Twente.

Wang, P., Bai, X., Billinghurst, M., Zhang, S., Zhang, X., Wang, S., He, W., Yan, Y., & Ji, H. (2021). AR/MR Remote Collaboration on Physical Tasks: A Review. *Robotics and Computer-Integrated Manufacturing*, *72*, 102071. doi: 10.1016/j.rcim.2020.102071

Weking, J., Mandalenakis, M., Hein, A., Hermes, S., Böhm, M., & Krcmar, H. (2019). The impact of blockchain technology on business models – a taxonomy and archetypal patterns. *Electronic Markets*, 1-21. doi: 10.1007/s12525-019-00386-3

Zott, C., Amit, R., & Massa, L. (2011). The Business Model: Recent Developments and Future Research. *Journal of Management*, *37*(4), 1019-1042. doi: 10.1177/0149206311406265