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Business Model Research on Industrial Augmented Reality: A Systematic Literature Review on the Current State and Future Research Areas

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Abstract. This systematic literature review aims to present the current state of business model research on industrial augmented reality (IAR) and suggest future research areas. Our analysis of 60 previous literature reviews on IAR shows that the business model perspective is missing from these reviews. To address this gap, we conducted a systematic literature review using eight scientific databases in late 2022. Although we aimed for a comprehensive literature search, a total of only 48 augmented reality (AR)-related business model publications were found, of which only six focused on IAR. To present the current state of research, these six publications were analyzed in terms of research purpose and results, the IAR application(s) studied, and the research methodology used. Based on this analysis, we propose future research areas, considering the suggestions for future research and the problems and challenges mentioned in the analyzed publications.

Keywords. Industrial augmented reality, business model research, systematic literature review, research agenda

1. Introduction

The use of augmented reality (AR) technology is changing the way customers are served, employees are trained, products are developed and designed, and value chains are managed [1]. It stands to reason that these multi-faceted changes are one reason why research on AR is an ever-growing area of study [2, 3]. One of the very first industrial applications of AR is described by Caudell and Mizell [4] of Boeing in 1992, who describe a prototype implementation of AR technology in aircraft manufacturing.

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Almost simultaneously with the advent of the internet in the mid-1990s, the number of publications in the field of business model (BM) research has also increased sharply [5, 6]. While a significant amount of BM research is directed towards understanding the BM concept itself [7], there are also numerous studies that use the BM concept as a unit of analysis, e.g., to study the use of specific technologies from a BM perspective [8–10]. However, to date, little attention has been paid to industrial AR from a BM perspective [11–13]. There is also no literature review (LRW) that presents the current state of BM research on industrial AR. This paper aims to fill this gap.

2. Theoretical Background

2.1. Industrial Augmented Reality

AR in general is a technology that allows reality to be enriched with virtual elements. An often cited definition of AR is that of Azuma [14], who defines AR as a system that combines the real and virtual, is interactive in real time, and registered in 3D. Although this definition is widely accepted in academia, there is also criticism of it, especially when it comes to industrial AR [15]. Industrial AR (IAR) is the application of AR in an industrial context, i.e., in the context of economic activities concerned with the processing of raw materials and the manufacturing of goods in factories. IAR applications exist along the entire value chain [12, 16]. In terms of Azuma's AR definition [14], applications where only virtual 2D overlays are placed over live video would not fall under this definition unless these overlays are combined with the real world in 3D. However, since this is the case in some prominent IAR applications, e.g., some AR-based remote maintenance applications [17, 18], we define AR more broadly as a technology that creates an environment in which reality is enriched with virtual elements.

2.2. The Business Model Concept and its Various Perspectives

The BM concept is relevant in practice and worthy of scientific investigation [19], which is also reflected in the ever-growing number of publications on BMs [5, 6]. However, there are different perspectives on the BM concept [20]: The *BM activities perspective* views a BM as ‘a description of the activities that the firm has put together in order to execute its strategy’, the *BM logics perspective* considers the core logic underlying the BM and describes ‘the flow of logical arguments that summarizes the logic of the business’, the *BM archetypes perspective* looks at the ‘generic logics of how firms do business’ and describes ‘general, well-known BM logics’, the *BM elements perspective* addresses the ‘essential elements in order to capture the important parts of a business’, and the *BM alignment perspective* considers the ‘interplay among BM elements’.

Given the purpose of this paper—to present the current state of IAR-related BM research—it is necessary to explain when we attribute to an IAR publication whether it is related to the BM concept. We attribute a BM perspective to an IAR publication whenever one of the above perspectives is evident and the term *business model* is used in a non-trivial way.

3. Related Work

To determine whether and to what extent existing LRWs on IAR already address the BM concept, we searched for previous LRWs on IAR. We searched eight scientific databases using the terms *review* OR *survey* OR *mapping* OR *meta-analysis* AND *augmented reality* at the end of 2022. Cross-references within the LRWs found to other existing LRWs on IAR were also considered. Publications containing only a short LRW section on IAR and answering research questions mainly with research methods other than a LRW were not considered. The same was true for LRWs that represent basic research on AR without an explicit focus on industrial application. As a result, a total of 60 full-text accessible LRWs on IAR were found. They were published between 2007 and 2022 and consist of about 70% journal publications.

The research topic of each LRW was evaluated based on the research aim and, if present, the research question(s) raised. Similar research topics were then grouped into a category that expressed the LRW's research focus. The following 13 research foci were identified: General application of AR in manufacturing [e.g., 21, 22]; application of AR in specific industrial sectors [e.g., 16, 23]; application of AR in specific industrial tasks [e.g., 24, 25]; AR maintenance research [e.g., 26, 27]; AR assembly research [e.g., 28, 29]; AR in human-robot collaboration [e.g., 30, 31]; visualization of communication cues in AR systems [e.g., 32, 33]; user-based AR research [e.g., 34, 35]; AR smart glasses [e.g., 36, 37]; interplay of AR and digital twins [e.g., 38, 39]; implementation of AR [40, 41]; gamification in AR systems [42, 43]; and artificial intelligence in AR systems [44, 45].

A focus on BMs was not apparent in any of these LRWs. Even the term *business model* appears only four times. However, the term is only used for rather general statements and does not represent the research focus even once. Thus, there is no LRW that addresses the current state and future research areas on IAR from the BM perspective.

4. Methodology

To present the current state of IAR-related BM research, we conducted a systematic LRW following the five-phase framework for literature review of vom Brocke et al. [46]. Figure 1 shows our application of this framework to this LRW.

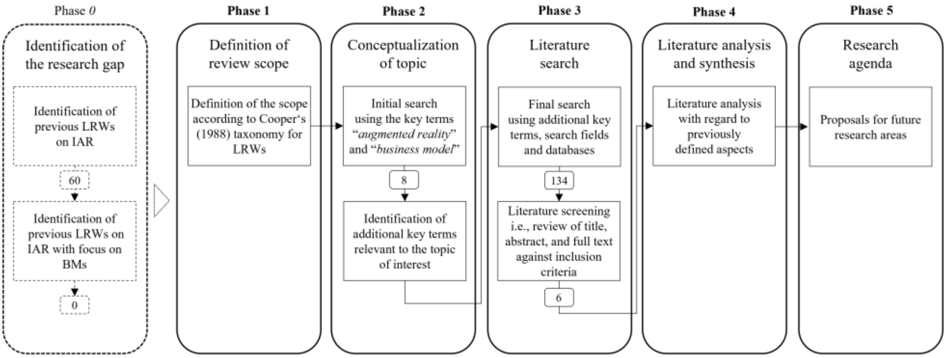

Figure 1. Application of the five-phase framework of vom Brocke et al. [46] to this systematic LRW. The steps within each phase are shown in the boxes; the arrows indicate the process flow; the numbers indicate the number of publications considered for further analysis in each case. Note: Identification of a research gap is not part of this framework. Therefore, we have referred to the analysis of previous LRWs on IAR as Phase 0.

To clearly define the scope of this LRW (phase 1), we rely on the established taxonomy for LRWs of Cooper [47] as proposed by vom Brocke et al. [46]. According to Cooper [47], a LRW is categorized by six characteristics, which we define for this systematic LRW as follows: The focus (1) is on is research outcomes, research methods, theories, and applications. The goal (2) is to integrate and synthesize the literature. The organization (3) can be classified conceptual, since we present the results according to certain aspects we investigated. The perspective (4) is neutral. Although we review the literature on IAR from a BM perspective, we do not take a particular position. Rather, we attempt to present the literature in a neutral manner. The intended audience (5) is specialized scholars who are concerned with IAR in a broader sense, not necessarily with IAR-based BMs. We aim for exhaustive coverage (6) because we assume that there is little research on IAR from a BM perspective. Accordingly, since we are likely to deal with only a few publications, we can be as comprehensive as possible and therefore consider all types of scientific publications, both in English and German.

Prior to the literature search, the topic of interest was conceptualized by defining key terms (phase 2). We conducted an initial database search using the key terms *augmented reality* AND *business model*. We used four scientific databases (i.e., ProQuest, Scopus, Web of Science and EBSCOhost) and searched only in the title search box. This initial search yielded a total of only eight hits (excluding duplicates). Since this is a very small numer of hits, we identified additional key terms relevant to the topic of interest based on these eight hits. We identified other AR-related terms such as *mixed reality* or *extended reality*, as well as hardware-related terms, such as *smart glasses* as other key terms. These key terms were logically combined to produce the search phrase used for the final database search.

The next step involved the final database search and literature screening (phase 3). Since our initial search yielded a total of only eight hits, we expanded the final search as follows: First, we expanded the search phrase to include the additionally identified key terms. Whenever appropriate, we also used the corresponding German terms. Second, we used Science Direct, IEEE Explore, ACM Digital Library, and Google Scholar as additional databases. Third, we extended the search to other search fields, such as abstract and author-supplied keywords (except for Google Scholar). Our final search now yielded a total of 134 full-text accessible publications.

Prior to phase four—the literature analysis and synthesis—we conducted the literature screening in three sequential steps: Step 1 aimed to identify publications with a focus on AR. In this step, 45 publications were excluded because their focus was on Industry 4.0 technologies in general rather than AR itself. Step 2 aimed to identify publications whose focus—in addition to AR—was on the BM concept. In 41 of the AR-related publications, the term *business model* is used in some way, but does not represent the focus of the publication, so these publications were also excluded. Step 3 aimed to identify the relevant publications whose focus is on the BM concept and on IAR. In this step, 42 publications were excluded as they were either exclusively or mainly related to AR applications in non-industrial sectors such as tourism, education, sports, gaming, healthcare, retail. As a result, a total of only six publications were identified that met all three inclusion criteria [11, 12, 48–51].

To achieve the aim of this paper, the publications were analyzed (phase 4) with respect to the following aspects: Research purpose and results, IAR application(s) studied, methodology used, suggestions for future research, and problems and challenges cited. The results of this phase are presented in section 5. A research agenda (phase 5) is presented in section 6.

5. Results and Discussion

5.1. Research Purpose and Results

The research purpose and results of Niemöller et al. [49] and Ohlig et al. [50] are very similar. Both works investigate the impact of using AR for remote services on the BM. Although the two works differ in their methodology and in considering slightly different IAR applications, both works conclude that the use of AR for remote services can affect almost the entire BM to varying degrees. Leone et al. [51], who investigate how AR determines BM improvements, also argue that the impact on the BM should be considered when applying AR solutions. However, as a result, Leone et al. [51] also conclude that AR can improve existing BM but does not necessarily lead to a new BM innovation or configuration.

The work of Röltgen et al. [12] and Grothus et al. [11] also have a similar research purpose. Both authors develop systematic approaches for the development of AR-based BMs. Based on the argument that the integration of AR requires adjustments to the BM and that the development of sustainable BM is a major challenge, a stepwise approach for the development of AR-based BM is developed in [12]. In contrast to [12], the approach for BM development described in [11] also considers VR applications.

In the work of Leino et al. [48], a proof-of-concept is presented to demonstrate the potential of using AR to innovate the *Upgrading BM* of a rock crusher manufacturer. The purpose is to answer questions on how to make the rock crushing machine upgrade business profitable, how to establish a successful BM, and how to effectively manage such upgrade projects using AR. The results show that the use of AR improves productivity due to a more fluent flow of information. In addition, AR enables virtual testing of proposed solutions before building physical products, as well as better planning and discussion of service activities [48].

5.2. IAR Application(s) Studied

Leino et al. [48] investigate a single and very specific IAR application. A manufacturer of rock crushers that provides machine upgrade solutions is considering the use of AR to visualize the upgrade solution to its customers and to support field workers in assembling the upgrade solution by overlaying the virtual solution on top of the old machine.

In the work of Niemöller et al. [49] and Ohlig et al. [50], two different AR applications are investigated. Both can be broadly described as AR-based remote field service applications. In [49], AR smart glasses are used to assist a person at a remote location either by a so-called remote expert or without the involvement of a remote expert, e.g., by providing step-by-step instructions. In [50], AR is also used for remote field service applications in two different ways, which differ in whether the person to be supported at a remote site is either part of the customer's staff (e.g., remote support of the machine operator) or part of the own company (e.g., remote support of the own service technicians). In both cases, the involvement of a remote expert is required.

In the work of Leone et al. [51], the use of AR smart glasses in the automotive industry is described using BMW as an example. AR is used for maintenance and repair purposes, e.g., to assist technicians in car dealerships when repairing vehicles. Using this and other non-industrial AR application examples, the authors of [51] demonstrate the BM improvements through the use of AR and the BM components affected.

5.3. Methodology Used

Only two research papers report on the use of primary data collection methods. Leino et al. [48] use questionnaires and interviews as data collection methods to evaluate the use of AR for the rock crushing machine upgrade business. Based on a swim-lane process diagram, the authors of [48] also apply a walk-through method in a focus group session to evaluate the newly proposed BM. In the work of Ohlig et al. [50], primary data is also collected through focus group discussions with industry experts to gain insights into the impact of the use of AR on the BM.

In contrast, Leone et al. [51] examine the literature on AR in management studies and AR implementations in industry, and Grothus et al. [11] also cite desk research as the research method used. Accordingly, only secondary data is collected in both papers.

The work of Niemöller et al. [49] and Röltgen et al. [12], on the other hand, is more conceptual in nature. In [49], no report is given on the use of a specific research methodology or data collection. The same is true for [12], however, the authors state that the proposed approach for the stepwise development of AR-based BMs has been successfully validated by applying it to an industrial case study.

5.4. Future Research Suggestions as well as Issues and Challenges Cited

Leino et al. [48], who present a proof-of-concept for using AR to innovate the *Upgrading BM* of a rock crusher manufacturer, state that ‘the degree of integration […] between the [AR] tools and the IT systems’ remains an open question. This seems to be a technical issue of the software interfaces that enable the integration of AR tools into existing IT systems. At the same time, the challenge is to identify the necessary IT systems whose integration adds value to the IAR application. Leino et al. [48] also conclude that 'technology maturity, usability and usefulness [of AR devices] are not yet quite good enough.' This is viewed differently in [18], where it is stated that some of the technological limitations of AR systems have now been overcome, and therefore AR is considered to be ready for industrial application. However, Leino et al. [48] expect this situation to improve soon, given the current pace of AR device development.

Niemöller et al. [49] only refer to research activities on service platforms when considering future research. In such service platforms, as also described in [52] and [53], AR could be integrated e.g. for remote service purposes.

Ohlig et al. [50] refer in particular to the desired monetization of AR-based remote services when considering future research. This is due to the fact that the companies studied did not yet offer such AR-based remote services, but were only in a testing or implementation phase. In [50], the connectivity of AR devices, which is a key resource of AR-based remote service BMs, is considered another challenge. Depending on the use case, either the remote service provider or the customer may be responsible for providing AR device connectivity. However, the obvious solution of using the customer's Wi-Fi may not be an option due to customer security and privacy concerns [50]. This seems to be more of an organizational challenge than a technical one, although there are also technical approaches to ensure AR-based remote service in environments without high-speed internet connections [18]. However, the issues mentioned above are more likely to be solved in practice rather than by future BM research.

6. Research Agenda

Based on our LRW, we suggest the following research areas that require further attention within IAR-related BM research:

Empirical BM Research on IAR: Only two publications reported on the collection of primary data. As AR seems to be gaining traction in the manufacturing industry [54, 55], this facilitates empirical research as more and more companies operate IAR-based BMs that can be empirically studied. Empirical research, for example, could classify [56], or evaluate [57] existing BMs.

IAR-specific BM ex-post Evaluation: The approaches proposed by [12] and [11] can be used to support the development of AR-based BMs. However, they permit an ex-ante evaluation of BMs. Thus, there is a lack of IAR-specific methodological approaches for ex-post evaluations of existing BMs. Ex-post evaluations could lead to the identification of best practices and help practitioners to understand which part of the BM (e.g., value proposition, pricing model) is working well and which is not.

AR-driven Field Service Platform BMs: Service platforms are an increasingly popular research area that is gaining momentum and has now evolved from a theoretical to an empirical research area [58]. However, with respect to AR-driven field service platforms, there are only conceptual approaches that consider AR as an enabler for such service platforms [e.g., 53]. This raises the question of the extent to which AR is an enabler for the BM of such service platforms.

Transferability of Findings from non-industrial AR-related BM Research: Based on our three-step literature screening approach to identify publications relevant to this LRW, we were able to identify—in addition to the six IAR-related BM publications—a further 42 AR-related BM publications that relate to non-industrial sectors. As it is not uncommon for industries to adopt, for example, established BM patterns from other industries [59], future research could address the question of transferability of findings from this non-industrial AR-related BM research to IAR-related BM research.

7. Conclusions

Since existing LRWs on IAR do not adopt a BM perspective, there was a lack of a LRW that presents the current state and future research areas of IAR-related BM research. This paper has filled this gap and shown that there is a general lack of research on IAR from a BM perspective—and not only in LRWs on IAR.

To present the current state of research, a systematic LRW was conducted using eight scientific databases. Both English-language and German-language publications were considered. Although 48 publications were initially identified that dealt with AR from a BM perspective, only six of these publications were related to IAR. These publications were analyzed in terms of research purpose and results, IAR application(s) studied, methodology used, suggestions for future research, as well as problems and challenges cited. Based on this analysis, we have proposed future research areas.

A limitation of this work is the small number of publications analyzed. Since we only considered publications that contain the term *business model* in the title, abstract or keywords, future work could also focus on IAR-related publications that, for example, focus on specific BM-relevant aspects (e.g., value propositions or customer segments), regardless of whether the term *business model* is used or not.

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