

Article

Strategic Aspects of Asset Management: An Overview of Current Research

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Abstract: Major shifts in the competitive environment encouraged a recent growth in the number of academic articles devoted to strategic aspects of asset management. Organizations start to recognize that a strategic approach to asset management becomes a source of sustainable competitive advantages and long-term survival in the turbulent environment. However, existing studies are largely case-specific in interpreting strategy and draw on various theoretical grounds and approaches. This leads to little theoretical and methodological consistency in understanding current findings and how to design future studies. The key goal of this paper is to systematically review the existing research through the analysis of over 700 articles devoted to asset management with a focus on strategic aspects. Our key contributions are positioning strategic asset management within the vast field of asset management research, describing the nature of strategic asset management research, and confirming that asset management strategies align with different levels of organizational strategy. We visualize the existing research field, and indicate gaps and underdeveloped areas of research. We also shortly outline future research directions based on our findings, thus encouraging a more coherent development of research on strategic asset management.

Keywords: asset management; asset management strategy; asset-intensive businesses; systematic literature review; scientific mapping

1. Introduction

Recently, there has been a significant amount of interest in research on strategic asset management both in academia and industry [1–4], while the majority of existing research is devoted to general, not strategic aspects of asset management (e.g., [2,4]). Managing physical assets is not a novelty for a wide range of asset-intensive industries (aviation, civil engineering, public infrastructure, etc.) as it is stemming from the 1960s and originally was an approach to maximize the value of asset portfolios throughout their life-cycle [5] also known as terotechnology (e.g., [6]). However, generally physical asset management did not imply special education or professional knowledge and various approaches were evolving including maintenance, logistics, engineering, etc. Such an approach did not address the rising pressures from the external environment and claims of various stakeholders. The need for asset management as a recognized discipline emerged due to the increasing complexity of technical nature across a wide range of industries and organizations [7]. As a result, asset management was widely accepted in capital intensive industries and infrastructure organizations [8].

Increasing competition, deregulation, external pressures, and technological advancement urge asset-intensive businesses to design new strategies allowing for their long-term survival. A considerable body of knowledge was developed, and the focus is changing gradually towards strategic, holistic, and systematic approaches focused on continuous improvement. Resting upon the existing literature [4,9–11] and ISO 55000 series of standards [7] within our study, we understand strategic asset management as a holistic approach

aimed at long-term sustainable development with the asset portfolio at the core of decision-making and developing competitive advantages across the whole organization.

However, despite the growing body of literature, there is still no coherent understanding of the phenomenon from a holistic perspective due to its origin that was practice-oriented and focused primarily on technical aspects [11,12]. The concept of strategic asset management lacks a clear focus as different interpretations are promoted by various communities of practice [4]; thus, the place and role of strategic asset management research remain unclear. For these reasons we pose our first research question (RQ1) as follows: *Is strategic asset management a salient research category in the field of asset management?* We address this question through employing scientific mapping, thus, a positive answer to RQ1 implies that research on strategic aspects of asset management has to be clearly visible as a separate stream within other major streams.

Traditionally, researchers refer to asset management strategies following either their own perception of what a strategy is or case-specific interpretations (relevant for particular organizations or industries), while their findings do not go beyond these particular cases, so it is hard to relate them to other studies in the field of strategic asset management. Overall, such studies contribute to the development of the body of research and a better understanding of the problem. However, since they draw on various theoretical grounds and approaches, there is little theoretical and methodological consistency in understanding current findings and, more importantly, how to design future studies devoted to strategic asset management [3]. In other words, the number of studies on strategic asset management is growing; however, the fact that the studies are so different and case-specific makes it hard for practitioners to implement the suggested strategies. The progress in developing the topic is hindered because of the essentially descriptive character of the cases; thus, there is a need to deeper analyze the nature of existing research. This provides rationale for our second research question (RQ2): *What is the nature (epistemological orientations) of strategic asset management research?*

Despite the fragmented nature of existing research, the idea that modern approaches to asset management have to become more integrated and holistic becomes dominating. Introducing a strategic approach to asset management seems to be a source of strong competitive advantage and should be considered within a broader organizational context. Recent research provides evidence that there is a link between introducing a holistic approach to asset management and improving organizational performance [10,13]. Considering a broader context implies that asset management goals should be consistent with the organizational goals across all levels of strategic decision-making [1,14]. The importance of exploring the possibility of aligning asset management strategy with organizational strategy is increasing as asset management implies higher-level managerial decisions concerning investment allocation, infrastructure expansion, modernization, and replacement as well as issues of outsourcing, leasing, and co-production. Increasing uncertainty and complexity draw multiple stakeholders into the decision-making process [15] while changing market requirements imply that the focus of asset management should extend beyond equipment and plant levels and encompass corporate and business objectives [1]. Since multidisciplinary competence seems to be a source of sustainable competitive advantages, we argue that strategic management literature provides well-established approaches that can serve as a basis for analyzing asset management strategies. At this point, we pose the third research question (RQ3) as follows: *Can we align asset management strategies to different levels of organizational strategy?*

Developing a more consistent understanding of the phenomenon from both theoretical and practical points of view seems to be crucial for further development of the topic. At the same time, there is evidence supporting that there is a possibility for generalization of the vast accumulated experience [16]; thus, there is a call for a systematic analysis of the existing body of research. This paper presents an attempt to address the outlined challenges through conducting an empirical study based on a mixed-technique analysis of 702 articles relevant to the field of asset management with a focus on strategic aspects.

The key goal of this paper is to systematically review the existing research on strategic asset management and explore the possibility to align asset management strategies with the overall organizational strategy across different levels of decision-making. While our study is positioned among other studies devoted to the meta-analysis of existing studies on asset management, we complement the literature by exploring precisely strategic aspects of asset management from managerial and organizational points of view. The originality of our study lies in the fact that existing reviews mainly concentrate on general aspects of asset management (e.g., [2,4,9]). Within the scope of our study, we refer to “asset-intensive businesses” as to those where the asset portfolio is dominated by engineering (plant, equipment, and infrastructure as, e.g., power grids, water, and drainage systems) rather than property assets. Our key contributions are as follows: (1) positioning strategic asset management within the vast field of asset management research employing a bibliometric analysis technique, (2) describing the nature of strategic asset management research via a systematic literature review, (3) confirming the possibility of aligning asset management strategies with different levels of organizational strategy performing a meaningful in-depth analysis of existing studies. Our paper contributes to the creation of a generalized picture of existing research indicating gaps and underdeveloped areas of research. We also outline future research directions based on our findings, thus encouraging more consistency in the development of research on strategic asset management.

2. Methodology and Data

We apply a mixed research strategy that combines techniques of systematic literature review and bibliometric analysis in order to answer the proposed research questions within the goals of our study. Our research design and data description are shown in Figure 1.

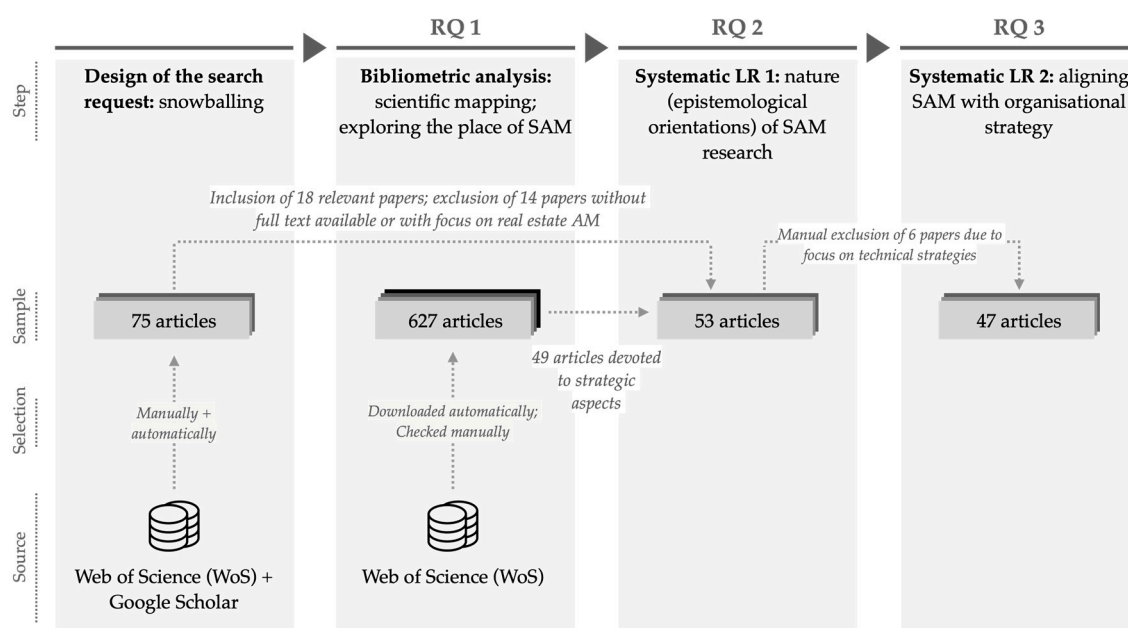


Figure 1. Research strategy (SAM refers to strategic asset management). Source: Authors' elaboration.

Thus, our research strategy implies the following steps: (1) designing the search request for further analysis, (2) answering RQ1 through bibliometric analysis with the use of the search request (visualization of the asset management field of research and exploring the place of strategic asset management), (3) answering RQ2 through a systematic literature review for exploring epistemological orientations of existing research on strategic asset management, (4) answering RQ3 through a systematic literature review of articles devoted precisely to strategic aspects of asset management (exploring the possibility of aligning asset management strategies to different levels of organizational strategy). There may be possible limitations of the employed methodology. First, bibliometric analysis can be

considered as lacking depth, while systematic review techniques can be prone to subjectivity. However, when paired, these methods complement each other, and our research strategy was designed in order to minimize bias and increase methodological accuracy. We pursued both automatic and manual approaches for sampling and further analysis of literature to increase validity and credibility of the obtained results. We ensured representativeness of our sample by using different sources and by including articles from high-quality journals.

2.1. Designing the Search Request

Before proceeding to the bibliometric analysis, we first conducted a systematic literature review to design the search request required for sampling. We applied the snowballing technique [17] to identify keywords that pertain to the broad field of research on asset management and further used them to select articles for analysis. We selected highly cited publications from field-specific journals indexed in the Web of Science (WoS) database and Google Scholar web search engine as we suppose that such journals provide a natural set of relevant articles. We chose Web of Science as it is a comprehensive database that covers a broad range of high-quality journals [18] and to a large extent overlaps with the Scopus database; thus, it is suitable for the purposes of our research [19]. This database also provides meta-data that is generally essential for conducting further bibliometric analysis [20] and is required by the selected software (authors, titles, keywords, keywords plus, abstract, authors' affiliations, total citations, publication year, subject category, etc.).

At the same time, the field of asset management is an emerging domain without a long tradition of regular publications in specific peer-reviewed journals [2]. Therefore, we performed an additional search with the Google Scholar web search engine. We included proceedings of conferences with a specific focus on asset management (mainly World Congress on Engineering Asset Management and Institute of Electrical and Electronics Engineers conferences) and relevant articles from journals with a more general focus. We suppose that these sources allow for triangulation and to a large extent cover the body of knowledge regarding asset management.

Our start set for performing snowballing was developed both manually (specific journals, conference proceedings, publications of prominent researchers and experts) and automatically (complementary search in WoS and Google Scholar). We combined approaches to overcome limitations of both methods, and thus, minimized the number of irrelevant papers and obtain a comprehensive set (as recommended in e.g., [21,22]).

We designed conditions for inclusion or exclusion of the papers including language (English), adequacy of the title, keywords and abstract to the topic (papers that were relevant to the focus of our study), publication venue (relevant peer-reviewed journals and conference proceedings), and author's contribution to the research field (history of previous publications). Our start set consisted of 20 papers that we used for further data extraction. The first iteration was backward snowballing which refers to examining the reference lists to identify new papers to include. At this point, we added 21 papers. The second iteration was forward snowballing which implies analyzing the papers that are citing the examined paper. At this point, we added 26 papers. Each candidate was thoroughly examined based on the designed conditions. If this information was insufficient for deciding on inclusion or exclusion, we studied the paper in more detail. Once we performed this step, all new papers were examined through the next iteration of snowballing. At this point, we added 8 more papers and stopped the cycle as we have reached saturation and no longer met additional terms that refer to asset management. Our final sample included 75 papers (listed in Table A1).

2.2. Bibliometric Analysis

With the results of the previous step, we designed our search request for WoS so that the term "asset management" appears in the title and included both articles and conference proceedings.

In order to avoid articles that contain the term "asset management," we incidentally require that the following terms (identified at the snowballing stage) appear either in the title, abstract, or keywords:

“physical asset,” “engineering asset” “infrastructure asset,” “facilities,” “utilities,” “fleet,” “asset-intensive,” “manufacturing,” “maintenance.” We excluded irrelevant research categories, such as business finance, medicine research, education, etc., which use a different notion of the term “asset management” or have a too narrow scope (computer hardware engineering) as we are mostly interested in managerial and organizational studies. The most relevant WoS categories appeared to be “engineering” (civil, industrial, electrical electronic, mechanical), “management,” “operations research management science,” and some computer science materials. We also made an additional iteration and added to the described earlier search request “strateg*” appearing in the title to make sure that we included all articles relevant to the focus of our study, which is strategic asset management.

Bibliometric analysis allowed to explore the nature of asset management research from the ontological position in conformity with a positivist approach. We employed the science mapping technique in order to answer RQ1, which allowed to characterize publications by a list of key terms and their mutual connections (frequency of co-occurrence). Key terms were allocated in a two-dimensional space, where terms with stronger links are located closer to each other on the map [23]. We selected VOS Viewer software in order to answer RQ1 due to evidence that the employed technique shows better performance, examination, and representation of data in comparison to software based on e.g., multidimensional scaling approaches [24].

We exported the references from WoS to EndNote online software for further analysis and automatically removed duplicates. Additionally, we manually checked the database in case if some irrelevant articles still appeared in spite of the filters (e.g., financial or corporate real estate articles). In total we created a dataset of 627 articles for conducting the bibliometric analysis pertaining to the period 1996–2019. The period was determined automatically, as the oldest relevant paper found with the help of our search request was published in 1996. The period can be explained by the fact that our focus was on managerial and organizational articles as we intentionally omitted purely technical categories that would probably pertain to earlier periods. The bibliometric analysis was conducted as follows:

1. On the first step, the software extracted terms with a condition “both from title and abstract” (in order to ensure the inclusion of all relevant terms as we already filtered articles by title).
2. On the second step, we chose the condition “use full counting of terms” (it allows to count any appearance of the term, not only its mere presence or absence as in condition “binary count”); thus, more than 13,000 terms were extracted.
3. On the third step, we chose the condition “minimum 5 occurrences of a term” (in order to reduce superfluous terms and ensure that only relevant terms are taken into account); as a result, the number of terms was reduced to 875.
4. Finally, we manually reduced this number to the 161 most relevant terms that present direct interest for the aims of our study.

The conducted bibliometric analysis allowed to present the structure of the research field on asset management with 5 salient categories and outline strategic asset management among other research categories (further described in Section 3).

2.3. Systematic Literature Review—Epistemological Orientations

While bibliometric analysis allows for generalization and visualization of the whole research field, the main limitation of this method is the lack of depth in analysis. In order to address RQ2, we refer to the methodology designed in a highly-cited paper by De Bakker et al. [25]. We explore the epistemological orientations of selected papers through theoretical, prescriptive, and descriptive contributions according to the norms of methodological positivism. We chose the positivist approach as we agree with the authors of [25] that such contributions seem to be most appropriate in business-related studies, while we acknowledge the importance of other approaches employed in various studies.

Thus, for the aims of our study, we further analyzed papers from our selected population that were extracted during the previous step by using the limitation “strateg*” in the search request. We also

checked the articles manually; thus, they represent a sample precisely focused on strategic aspects of asset management (49 papers out of 625 extracted from the WoS database). Our final sample for analysis consisted of 53 articles as we (1) included 18 relevant papers found during the snowballing stage (not indexed in WoS or did not fit the search request but are relevant for the aims of our study) and (2) excluded 12 papers without available full texts and 2 papers with a focus on real estate asset management. We intentionally excluded papers without available full texts from our analysis as a full paper provides a better basis for establishing epistemological orientation. We argue that this sample is representative as we included relevant papers found both automatically and manually in order to ensure validity and credibility of results.

2.4. Systematic Literature Review—Contextualization of Strategy

To answer RQ3, we examine whether universally accepted strategic management theories are appropriate as a basis for aligning asset management strategies with the overall organizational strategy. We excluded 6 papers (from the sample of 53 articles analyzed in the previous step) as they are focused on optimization strategies. We proceed with a meaningful analysis of 47 articles to explore the contextualization of asset management strategies by various authors with a focus on different levels of decision-making.

We classify the selected papers employing a concept-centric approach paying attention to specific units of analysis [26] (presented by different levels of organizational strategy) relying on the hierarchy of strategies concept. Units of analysis serve as evidence of asset management strategy contextualization. We refer to four main levels of strategy: corporate, business (competitive), functional, and operational that differ in focus, objectives, planning timeframe, and performance criteria. We limit our analysis to classifying asset management strategies according to the following questions that help to indicate the level of strategy (referring to [27]):

- Corporate level: How to gain advantage from managing a set of businesses?
- Business/competitive level: How to gain and sustain a competitive advantage for a single line of business?
- Functional level: How to manage a particular activity within a business in ways that support the business strategy?

We also refer to the operational level (how to manage activities of strategic significance within each functional area?) in order to both exclude papers that have a focus only on technical issues and also provide a broader picture of strategic asset management within the whole organization.

3. Results

3.1. Exploring the Importance of Strategic Asset Management Research in the Field of Asset Management

The conducted analysis employing snowballing showed that there is no universally accepted thesaurus on asset management and different authors refer to the same concepts in various terms. Many articles are industry-specific and object-oriented. We noticed that various authors referred to the issue of asset management applying different terminology and focusing on different aspects of the research domain, e.g.,:

- Asset (physical, engineering, fleet, infrastructure)
- Asset-intensive business
- Facilities management (excluding real estate)
- Asset management vs. maintenance
- Corporate and enterprise asset management
- Strategic asset management and asset management strategy
- Maintenance (including performance measurement)

- Asset life-cycle management

Extracting these constructs was essential before conducting the bibliometric analysis in order to identify relevant terms for designing the search request that would cover the broad issues addressed in multiple disciplinary fields. The science mapping technique allowed us to create a visualization map of the research field devoted to asset management on the basis of 627 papers found in WoS as seen in Figure 2. Terms co-occurrence frequencies serve as an input for the mapping technique and terms are located in a two-dimensional space. VOS Viewer software creates a map that shows the frequency of occurrence of a term (the bolder the circle, the more frequently the term is used in the selected population of articles) and the link between terms (the closer the distance, the stronger the link). The link is determined by the frequency of co-occurrence in the title, keywords, or abstract.

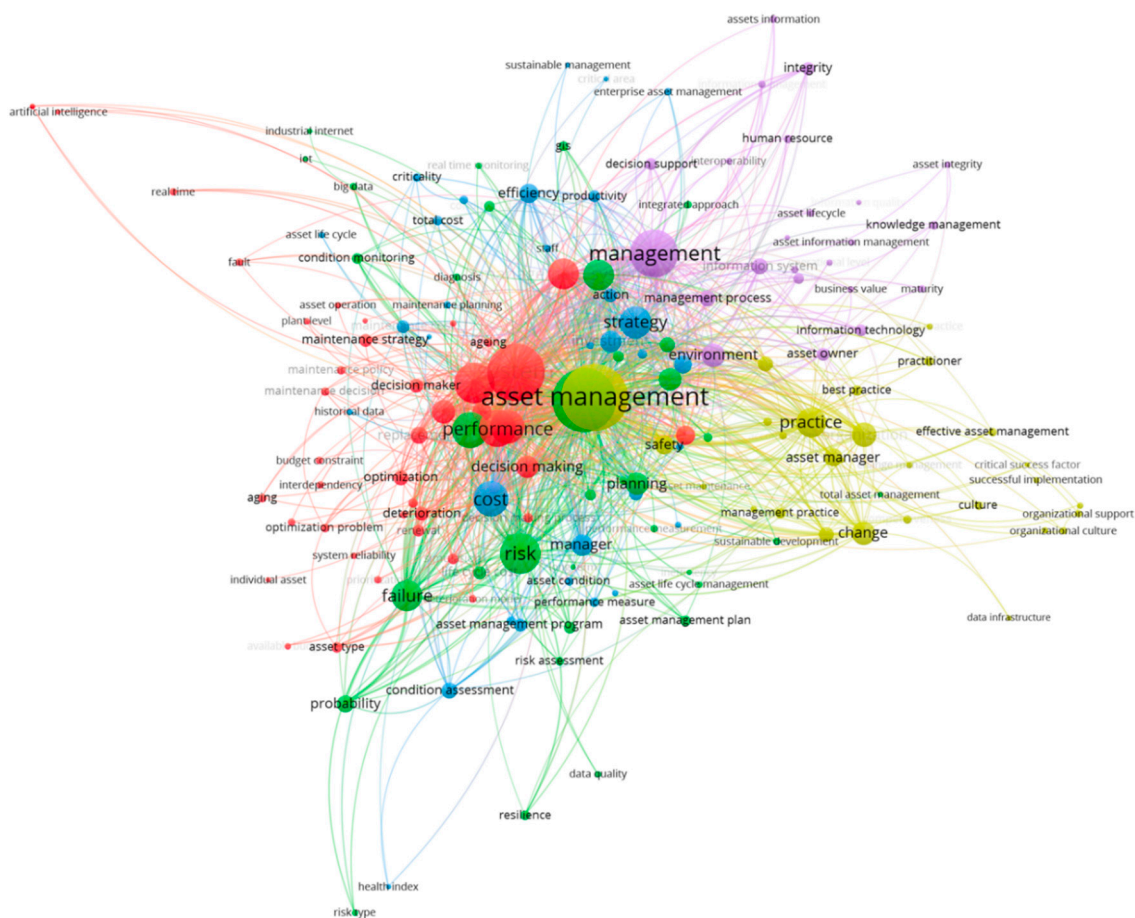


Figure 2. Visualization map of existing research devoted to asset management. Source: Authors' elaboration.

This step allowed us to answer RQ1 and outline several clusters demonstrating the main research categories in the field of asset management. Initially, we obtained 12 clusters out of 161 terms; however, the clusters were significantly disproportional in size, while small clusters comprised terms from a very similar context. One possible explanation is that we chose synonymous phrases when we manually reduced the number of terms. Different authors refer to the same concepts in various ways (e.g., “available budget” and “budget constraint”), also there are differences in spelling (e.g., “ageing” and “aging”), so we left similar concepts in order not to miss any important links. Another possible reason is the close interconnectedness of different studies and concepts, which still can form small clusters of similar research, but with slightly different foci. After several iterations, we achieved 5 clearly defined clusters (marked in different colors in Figure 2) with putting 20 items as a minimum requirement for the size of a cluster (Table 1).

Table 1. Major categories within research devoted to asset management.

#	Cluster	Key Terms	Description
1	“Operational level decision making” (40 items)	Ageing, aging, artificial intelligence, asset management strategy, asset operation, asset type, available budget, budget constraint, customer satisfaction, decision, decision maker, decision making, decision making process, deterioration, deterioration model, effective management, failure rate, fault, flexibility, individual asset, integrated control, integrated control, interdependency, maintenance, maintenance decision, maintenance policy, maintenance strategy, management system, optimization, optimization problem, performance, plant level, prioritization, real time, reliability, renewal, replacement, simulation, stakeholder, system, system reliability	Focus on system reliability, maintenance, modelling risk, failure and renewal/replacement within budget constraints, control and plant level decision making
2	“Asset life cycle management” (36 items)	Asset, asset life cycle management, asset management plan, asset performance, big data, complexity, condition, condition data, condition monitoring, coordination, data quality, diagnosis, failure, GIS (geographic information system), industrial internet, inefficiency, integrated approach, IoT, knowledge, life cycle, life cycle cost, life cycle management, long term, performance measurement, planning, probability, real time monitoring, resilience, risk, risk assessment, risk management, risk type, short term, sustainable development, technology, total asset management	Managing individual assets/group of assets over their life cycles with a focus on information technology and risk management
3	“Strategic asset management” (32 items)	Action, asset class, asset condition, asset lifecycle, asset management program, asset management tool, condition assessment, cost, critical area, criticality, decision support tool, effectiveness, efficiency, enterprise asset management, health index, historical data, investment, life cycle cost analysis, maintenance cost, maintenance manager, maintenance planning, maintenance process, maintenance requirement, manager, performance measurement, productivity, resource allocation, staff, strategic asset management, strategy, sustainable management, total cost	Focus on enterprise level asset management, technical/economic efficiency, managerial decision making and strategy
4	“Organizational aspects of asset management” (28 items)	Accountability, asset maintenance, asset management, asset management framework, asset management organization, asset management practice, asset manager, best practice, change, change management, competitiveness, critical success factor, culture, data infrastructure, effective asset manager, good practice, key success factor, management practice, organization, organizational change, organizational culture, organizational support, practice, practitioner, profitability, safety, successful implementation, sustainability	Focus on change management, organizational culture and managerial practice
5	“Asset information management” (25 items)	Asset information, asset information management, asset integrity, asset lifecycle, asset owner, assets information, business value, continuous improvement, decision support, environment, human resource, information management, information quality, information system, information technology, integrity, interoperability, knowledge management, lifecycle, management, management process, maturity, operational level, performance evaluation, risk analysis	Focus on information technology and knowledge management

As it can be seen from Table 1, 5 clusters can be discerned:

- (1) “Operational level decision making” with a clear focus on maintenance, decision making and system reliability;
- (2) “Asset life cycle management” with a clear focus on managing asset life cycles and risk with information technology support;
- (3) “Strategic asset management” with a clear focus on strategy, efficiency, enterprise level decision making;
- (4) “Organizational aspects of asset management” with a clear focus on change, culture, and human factor;
- (5) “Asset information management” with a clear focus on the role of information technology in supporting decision making and continuous improvement.

Obviously, a strategic approach to asset management is a clear research category within the field of asset management. Additionally, we studied implicit connections between cluster (3) and other clusters through related terms; thus, cluster (3) is related to:

- Cluster (1) through terms “asset management strategy,” “condition,” (in (1) asset condition is described e.g., through “ageing” and “deterioration”), “decision making” (“decision support tool”

To answer RQ1 more exhaustively, we additionally explored the dynamics of publications regarding strategic asset management based on our bibliometric search in WoS (Figure 4).

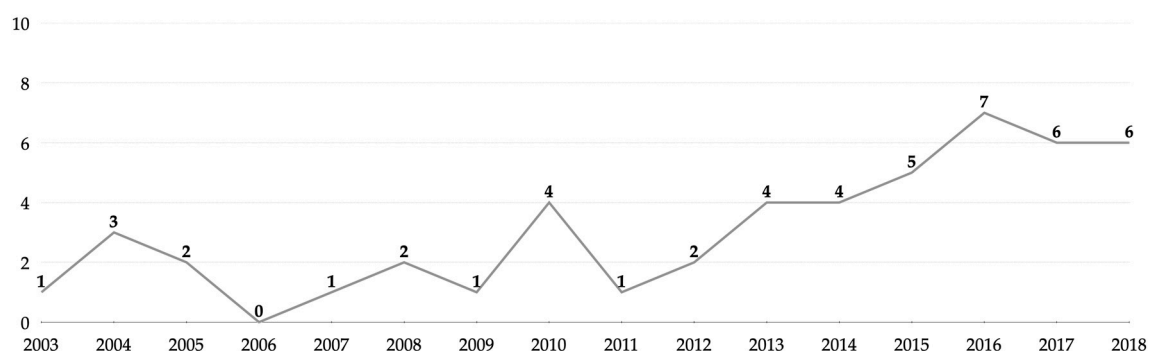


Figure 4. Dynamics of publications devoted to strategic asset management. Source: Authors' elaboration.

Since 2011 interest in strategic aspects of asset management is growing. Nevertheless, research on strategic aspects still presents only a small fraction of the obtained population of articles (49 out of 627 or ~8%).

Answering RQ1, we can confirm that strategic asset management is a well-defined and important research category (judging on the mapping results and dynamics of publications). However, the body of research seems to be fragmented and still to a high degree disseminated within research on maintenance, technical issues, and operational-level strategies. This calls for a closer analysis of the articles devoted precisely to strategic asset management.

3.2. Exploring the Nature of Strategic Asset Management Research

As described in Section 2, at this point, we excluded 12 papers due to the impossibility of finding full texts (mainly conference proceedings and book chapters) and 2 papers as they were more focused on real estate issues. We also added to our analysis 18 papers that we found during the snowballing process that are not indexed in WoS or did not fit the search request but are relevant for the aims of our study (e.g., works on strategic maintenance by Tsang [28–30]). We further refer to [25] and classify the epistemological orientation of the selected 53 papers through theoretical, prescriptive, and descriptive contributions.

First, we reviewed the abstracts to establish epistemological orientation of the articles. In the majority of cases, information from the abstract seemed to us insufficient for making a decision on categorization (e.g., too short or too broad description); thus, we deeper analyzed the full text of the paper. Also, following [25] in making our decision about the epistemological orientation of a paper, we used both our own judgment (all authors of the current study independently from each other) and the authors' personal indication of the contribution. The results of categorization are presented in Table 2.

Table 2. Epistemological orientation of papers devoted to strategic aspects of asset management.

Contribution of Papers		References
Theoretical ($n = 24$)	Conceptual (10)	[1,8,14,15,31–36]
	Exploratory (10)	[11,37–45]
	Predictive (4)	[13,46–48]
Prescriptive ($n = 11$)	Instrumental (9)	[49–58]
	Normative (2)	[59,60]
Descriptive ($n = 18$)	Descriptive (18)	[3,10,14,28–30,61–72]

Papers were classified as having a theoretical contribution if they contributed to the systematic understanding of strategic asset management as a phenomenon. Both exploratory and predictive papers rely on empirical data, mostly on case-specific or industry-specific data. Exploratory papers predict relationships between different aspects of asset management, while predictive papers deal with formulating and testing hypotheses (e.g., link between asset management and performance). Conceptual papers arrive at conclusions based on existing theoretical insights in the field of asset management and propose analytical frameworks.

Papers were qualified as prescriptive if they provide a “recipe” for industry practitioners and professionals in asset management from the strategic point of view. Instrumental papers mostly deal with models and guidelines that should enhance the execution of asset management in organizations and improve performance, but without actual empirical evidence in favor of performance improvement. Normative papers deal with issues of sustainable development with strategic asset management as the basis of decision-making.

Papers were qualified as descriptive if they provide expert opinion, describe indirect evidence, or report data that is valuable and relevant to practitioners and researchers. Such papers do not provide a significant theoretical or practical contribution to the field of asset management.

Our analysis indicates a lack of studies linking asset management strategies to organizational strategy or exploring a holistic perspective on strategic asset management. There is also a lack of empirical evidence in studying the link between asset management strategies and business performance, competitive position, and competitive advantages.

The majority of papers in our sample appeared to provide either a theoretical (45.2%) or descriptive (33.9%) contribution, while 20.7% of papers have a prescriptive orientation. Among the theoretical papers, conceptual or exploratory are presented by an even number (42% of each type), and only 16% of papers appeared to be predictive. Only two papers from the sample were found to have a normative orientation and were primarily devoted to sustainability issues. Most of the prescriptive papers (81%) are instrumental.

Our analysis demonstrates an abundance of theoretical and descriptive studies with a wide variety of specific interpretations considering the concept of “strategy” regarding asset management. We also find that research on strategic asset management lacks consistency and is presented mostly by specific cases and opinions. On the other hand, these cases seem to serve as a good basis for generalization. The patterns we observed are supplemented by further meaningful analysis in answering RQ3 and aligning asset management strategies with the organizational strategy at different levels.

3.3. Exploring the Possibility to Align Asset Management Strategies With Different Levels of Organizational Strategy

To answer RQ3, we classified the papers from our dataset employing a concept-centric approach [26] paying attention to the contextualized interpretation of what is asset management strategy according to different levels of management (referring to the concept of the hierarchy of strategies as described in methodology). Information from the abstracts seemed to us insufficient for deciding on categorization; thus, we referred to full texts of the papers. We used both our judgment (all authors of the current study independently from each other) and the authors’ indication (implicit or explicit). We noticed that sometimes authors indicate strategy and its pertinence to an organizational level within a specific context or according to the authors’ interpretation of strategy; however, we base our classification on the understanding of strategy within different levels of management that is established within strategic management literature (as in [27]) to enable generalization.

Our analysis (Table A2) shows that 92% of papers (47 out of 53) are devoted to organizational aspects of strategic asset management, and we proceed with analyzing these papers. The remaining 6 (highlighted in grey) are mostly focused on operations research and do not contribute to the goals of our study. The resulting categorization conforms with previous results and demonstrates that despite the fragmented nature of research, lack of solid theoretical foundations, and mainly case-specific or industry-specific studies, there is a significant possibility of generalization [16]. We further outline the

focus of decision-making regarding asset management within all levels of strategy according to the chosen approach.

Corporate level strategy (focused on gaining advantage from managing a portfolio of businesses as referred to in [27]) seems to determine the limits of decision-making concerning asset management within the vision, mission, values, and long-term strategic objectives of the whole organization. Decision-making is to a high degree influenced by the organizational context and stakeholders' expectations. It is especially important for public agencies and infrastructure companies that tend to have high monopoly power due to economies of scale and, thus, operate in regulated environments with limited public funding (e.g., [15]). Companies operating in competitive environments have to embed the global context and stakeholders' interests due to increasing competition and changes in the political, economic, social, and technological dimensions to stay competitive and survive in a long-term perspective (e.g., [1,3]).

Authors highlight the rising importance of sustainability, safety, social responsibility issues, and increasing environmental pressures that should be embedded in long-term strategic planning of the asset portfolio (e.g., [13,70]).

Decisions on resource allocation towards asset management predispose the choice between alternative options of strategic development: greenfield investments, expansion, replacement, or disposal of assets [36]. Prioritization of these limited resources implies that asset management strategies should answer the "make-or-buy" question and carefully evaluate the relevance of in-house production, mergers, outsourcing, or co-production to achieve higher returns on investments and better overall organizational performance.

The majority of authors emphasize that senior management support, leadership and motivation, stakeholder management, communication, and feedback within all levels of decision-making play an important role in strategic asset management, ensuring adaptation to change and continuous improvement (e.g., [38,55,69,72]). Strategic asset management on the corporate level, thus, deals with resource availability determined by constraints both of external and internal nature. The goal of a corporate asset management strategy is long-term planning of the asset portfolio, ensuring profit maximization and overall business performance improvement.

Business targets and strategic objectives on the *competitive level of strategy* (focused on gaining competitive advantages within a single line of business as referred to in [27]) are accomplished based on managing the asset portfolio, ensuring higher quality and lower operational costs. Strategic decision-making regarding the exploitation of limited resources allocated for asset management has to take into account industry and market structure, competitive demands, customer expectations, and benchmarking of best practices (e.g., [1,3,31,36,61]).

Decisions considering asset management on the business level imply the choice between alternative options of the basis for competition: cost and price, quality and quantity of products and services (which corresponds to the ideas of Porter [73,74]). Companies have to ensure both economic efficiency in terms of revenue generation and profit margin as well as cost-effectiveness. Infrastructure companies and public agencies that operate in regulated markets have to employ asset management strategies that ensure minimal costs to the public. Companies that operate in competitive markets have to meet their commercial goals and decide how to create additional value and meet client's expectations introducing customer-oriented and value-driven strategic approaches to asset management.

Competitive priorities (cost, quality, or flexibility) depend on the existing barriers to entry, availability of resources, scale efficiencies, and sources for differentiation within the industry. These factors influence the organizations' competitive position, while asset management and maintenance are key to developing sustainable competitive advantages [39].

Developing resources and capabilities (corresponding to ideas of the resource-based view of the firm [75–77]) in strategic asset management seems to be highly important in the process of gaining competitive advantage. Companies have to determine key capabilities and core competence in order to

meet the expectations for business and financial performance, focusing on customers and accountability for results (e.g., [10,13,28,32,35]).

As opposed to corporate and business level decision-making aimed at long-term planning, *functional asset management strategies* (focused on managing a particular activity to support the business strategy as referred to in [27]) seem to be focused on mid-term objectives and tactical planning. Asset managers are responsible for direct governance of the asset portfolio through establishing specific asset management systems, processes, and practices. Their decisions are focused on purchase, replacement, and rehabilitation of the asset portfolio to balance performance, risk, and costs (e.g., [1,13,40,62]). A strategic asset management system puts an emphasis on key performance indicators aimed at creating value from assets, commitment to continuous improvement, and asset management maturity. Asset management programs, policies, and plans should assign roles and responsibilities and incorporate performance indicators in conformity with higher-level strategic objectives.

Many authors emphasize the importance of organizational support, communication, and feedback, developing an asset management culture. Information and decision networks are crucial in asset design, risk management, and optimization of asset management processes; thus, they increase the role of information management, communications, relationship management, and system integration (including integration with operations) [10]. Organizational structure seems to be a supporting medium facilitating these processes [51].

Asset life-cycle management, risk management, and asset-related supporting activities are intended to support decisions on the optimal maintenance and renewal strategies, allocation of scarce resources, employment of reactive or proactive approaches. Asset managers are responsible for keeping assets healthy and operational, maintaining and optimizing asset life-cycle cost and value in a long-term perspective based on asset criticality and failure predictions. Designing replacement and maintenance programs implies achieving optimal capacity, higher equipment effectiveness, reliability and flexibility of the system, and as a result, lower maintenance costs, higher profit-making capability, and increased financial returns on assets (e.g., [11,14,42,48]).

Our analysis revealed a very important insight: strategic asset management on the functional level seems to have two opposing facets. From one side, it requires a certain degree of standardization (e.g., adoption of ISO 55000 guidelines and design of holistic asset management systems), from the other side, we observed idiosyncrasy in practices, policies, and approaches across industries and organizations.

We also briefly outline asset management strategies on the *operational level* (focused on managing activities of strategic significance within each functional area as referred to in [27]) as it provides a wider picture. The main focus is on operational planning, asset data, field staff engagement, service delivery, and implementation of asset management plans from a short-term perspective. This is the level of actual inspection and audits, operation, asset maintenance, and condition monitoring. Field staff is in charge of measuring asset performance and collecting asset data on criticality, risk, and failure, which emphasizes the role of information quality. Decisions are focused on almost immediate execution, reaching operational excellence considering equipment constraints and higher-level strategic objectives (e.g., [29,62,78]).

Our analysis revealed that frequently asset management strategy is referred to in an ambiguous or inexplicit way without a direct indication of the level of organizational strategy, but with indirect reference (e.g., mentioning external environment, mission and vision and stakeholders' expectations implying corporate-level decision-making). Despite the lack of a transparent division between different levels of strategy, our results demonstrate that if we refer to "strategy" from managerial and organizational points of view (in our case using the hierarchy of strategies concept [27]), then the concordance of asset management strategies with the overall organizational strategy becomes straightforward. The obtained results also confirm that the existing body of research is subject to significant generalization that can serve as a basis for further studies on strategic aspects of asset management.

We suggest that referring to well-established managerial theories can lead to less ambiguity and help authors separate their studies devoted to strategic asset management from operations research

and optimization modelling. Such an approach would lead to a more coherent development of the body of research on strategic asset management. Our analysis demonstrates that even without an explicit indication of strategy, we could define certain patterns that refer to a precise level of decision-making. We further discuss our results and argue that different theoretical approaches from strategic management literature are suitable for analyzing asset management strategies on different organizational levels.

4. Discussion

4.1. Summary of Findings

We first outline major findings within the raised research questions.

Answering RQ1, we conducted a bibliometric analysis demonstrating through science mapping that strategic asset management is a salient category within the asset management body of research with a distinct focus, while implicitly and explicitly connected with other categories. Further analysis also shows that the number of articles devoted to strategic aspects of asset management, while being relatively small, is increasing throughout recent years. These findings provide a rationale for a closer examination of the existing literature on strategic asset management. Within RQ2, we explored the nature of strategic asset management research through identifying epistemological orientations of articles from our sample. The performed categorization demonstrated an abundance of theoretical and descriptive studies with a wide variety of specific interpretations considering the concept of “strategy” in relation to asset management. There is also a lack of studies focused on the link between strategic asset management, organizational strategy and performance with a predominance of conceptual frameworks and “recipes for action.” Nonetheless, in compliance with previous research, a closer investigation confirms that the accumulated experience is subject to significant generalization. The conducted concept-centric analysis of the selected papers demonstrates that despite conceptual ambiguity and variety in interpretations, asset management strategies indeed can be aligned with the organizational strategy; thus, positively answering RQ3. We identified several important insights and want to elaborate on the results to assume which theoretical foundations are suitable for further studies of asset management strategies. We discuss the possible approaches from strategic management that can be employed for future studies of strategic asset management.

4.2. Further Interpretation of Results Within Strategic Management Literature

The suggested references and interpretations are non-exhaustive and non-conclusive; however, they provide a basis for further scientific discussion and a wider deliberation of the topic.

We noticed that when referring to corporate-level strategies, authors divide decisions into several categories that we can largely describe as follows: adaptation of the asset portfolio to external change (institutional and regulatory pressures, stakeholder claims); “make-or-buy” decisions (develop assets inhouse or outsource services) and decisions on investments (greenfield investments, expansion, replacement or disposal of assets); leadership and senior management support, culture, and communication. These categories can be addressed from different theoretical angles.

For instance, decisions on the corporate level are to a certain extent shaped by the institutional forces, which seems to be especially important for asset-intensive businesses operating in regulated markets. Nevertheless, with increasing demands from stakeholders in competitive markets, it becomes of highest importance for asset-intensive businesses in general. Each particular organization is embedded in a larger environment and may be influenced by industry standards, societal norms, shared cognitive perceptions, and legitimate strategy techniques. The legitimation and influence of such “best practices” are related to ideas of institutionalism [79]. Strategic practices become institutionalized if they provide desirable performance outcomes within particular industries. According to theory, this leads to mimetic and normative isomorphism in a wide array of industries [80]. Companies generally demonstrate certain strategic behavior in direct response to different institutional pressures

from compliance to resistance depending on varying institutional conditions [81,82]. This is an interesting avenue for future studies on asset management strategies and adaptation to change in both competitive and regulated environments.

Answering the “make-or-buy” question, allocating investments and deciding on expansion to further markets through diversification is in the focus of researchers exploring optimization of the firm size. Collis and Montgomery [83] argued that decision on firm size is a choice between corporate hierarchy (vertical integration) and market relationships. This choice depends on certain factors, such as the existence of competitive advantages, the efficiency of market mechanisms or demand for coordination of resources. Another possible approach is growth through the following alternatives: market penetration, market development, product development, or diversification [84]. Choosing between investing in the expansion of the asset base (including for entering new markets) and increasing the service life of the existing infrastructure (to compete in current markets) is closely related to the issue of exploration versus exploitation and organizational ambidexterity [85,86].

Strategic organization design [87] and leadership studies (e.g., [88–90]) seem to provide an appropriate basis for further discussion on leadership and communication in support of developing asset management systems contributing to the achievement of long-term strategic objectives of the organization.

When dealing with business (competitive) strategies, authors fall into two groups: (1) advocating the importance of industry structure in developing asset management strategies (following Porter’s thinking [73,74]), and (2) emphasizing the importance of resources and capabilities for developing sustainable competitive advantages based on the asset portfolio (following the ideas of the resource-based view [75–77]).

Industry structure urges companies to decide on their competitive positioning, which closely relates to Porter’s ideas on generic strategies and industry forces shaping strategy [73,74]. Companies can choose their competitive position on the market through balancing between technical and revenue-generating efficiency [91] or between market control and value orientation [92].

On the other side of the spectrum, the resource-based view (RBV) provides a rationale for developing competitive advantages based on combining resources and capabilities and developing core competence of the organization [77]. RBV implies that localized contexts have a value-creating potential; thus, emphasizing the idea of idiosyncrasy found in micro-contexts of organization. The unique structure of organizational resources (both tangible and intangible assets) is a source of competitive advantage and explains heterogeneity between asset management strategies that apply different firms. Strategic asset management can be a source of strong and sustainable competitive advantages and certain activities involved in asset management may be seen as core competencies [77]. The propositions of RBV can also be supplemented with the dynamic capabilities perspective as it is precisely focused on how firms survive in dynamic markets in a long-term perspective [93,94].

The issues of competitive positioning, competitiveness, and developing sustainable competitive advantages seem to be a promising avenue for further research due to the major challenges that asset-intensive businesses face in recent decades, including deregulation, globalization, and technological advancements across a wide array of industries.

The analysis of functional level strategies provides us with important insights regarding the nature of strategic asset management. We noticed that authors tend to argue that holistic asset management systems should conform with certain guidelines (mainly ISO 55000) to ensure commitment to continuous improvement, communication with senior management, and considering the organizational context. This idea corresponds to ideas of isomorphism presented in institutional theory. However, the institutional perspective is frequently criticized for largely omitting the active role of organizations. Interestingly, our results also show that there is a noticeable level of heterogeneity between the actual design of asset management systems and strategies. Asset managers are key actors responsible for the establishment of specific processes and practices for managing the asset portfolio. We assume that this

heterogeneity stems from the “black box” of strategy [95] that hides what exactly happens during the process of “strategizing”.

In strategic management literature, these issues can be addressed within the developing research stream called “strategy-as-practice” (e.g., [96,97]). We argue that the functional level of asset management strategy is of particular interest for future studies as it is the level where direct governance of the asset portfolio takes place. Whittington [98] suggests a framework for intra-organizational analysis that includes three main elements: practices, praxis, and practitioners. Practices refer to routines, norms, and procedures for “strategizing” in a broad sense, while praxis (analysis, formulation, implementation, control) stands for the actual activity of people (practitioners) within or outside the organization. A very important idea supported by existing research is that not only senior managers pertain to the group of practitioners, but also middle-managers and outside actors, such as advisers, consultants, lawyers, business school instructors, etc. (e.g., [99,100]). While lacking a formal role in formulating strategy, middle-managers, operational-level personnel and outside actors also shape the strategy through interpretation and engagement in different practices. It should be understood that strategic asset management is about what “asset managers do,” not about what “assets do.” Such an approach provides a broader insight describing strategy as a social practice. The strategy-as-practice approach does not provide a full picture of what exactly is a practice and how it becomes praxis within the company (i.e., asset management practices embedded in different organizations). However, it allows for further contemplation of the processes related to strategic asset management, which is a multilevel phenomenon penetrating the whole organization and highly dependent upon different agents within and outside the company.

Thus, “strategic asset management” as a phenomenon may be analyzed from different theoretical angles provided by strategic management literature. When we presume that an “asset-intensive business” is a separate category, e.g., like “manufacturing,” “retail,” “wholesale,” or “service,” then we can also more transparently refer to what an asset management strategy is across all levels of decision-making. Manufacturing is somehow a too narrow category as not all manufacturers are asset-intensive (small-scale, farming, etc.) and not all asset-intensive companies produce tangible consumer or industrial goods (e.g., railway or electric utilities), so we can highlight asset-intensive business as a separate category of business, while also including manufacturing companies [4,15,28]. If we continue our analogy, retailers have different structures, business models, and modes of creating additional value; likewise, asset-intensive businesses differ in structure, composition, and allocation of their physical assets to balance risk, cost, and performance. Within the scope of our study, we refer to capital intensive industries, where the asset portfolio is dominated by engineering assets (plant, equipment, and infrastructure as, e.g., power grids, water, and drainage systems). We want to emphasize that we refer to these categories from a business model point of view, although we admit that within the latter four categories, companies deal with real estate asset management; however, as we mentioned earlier, this research stream is beyond the scope of our study, while we hope to address this issue in further studies.

4.3. Implications, Limitations and Future Research Directions

The results of our study conform with previous research and complement the existing literature with deeper insights on strategic aspects of asset management from managerial and organizational points of view. Our study is positioned among other studies devoted to the meta-analysis of the existing body of research on asset management. While previous studies mainly concentrate on the general aspects of asset management (e.g., [2,4,9]), we focus precisely on strategic aspects of asset management.

While being theoretical, our findings have certain practical implications. Our analysis shows that strategic asset management can be a source of creating sustainable advantages both for competitive and regulated environments. The results indicate that strategies across all levels of decision-making have to be interconnected and primarily focused on the configuration and management of the asset portfolio while taking into account the external pressures, competitive environment, and budget

constraints. We provide industry practitioners and asset management professionals with evidence that strategic decisions on managing the asset portfolio differ depending on the organizational level, and we explicitly outline the differences and scope of decision-making. We also emphasize that the focus of decision-making changes gradually towards more asset-specific and short-run goals when progressing from the corporate to the functional level. Thus, our results can serve as a basis for designing asset management systems with a focus on strategy and coherent decision-making.

There are some possible limitations of our study due to the employed methodology. Bibliometric analysis can be considered as lacking depth, while systematic review techniques can be prone to authors' bias and subjective interpretation. However, when paired, these methods complement each other, and our research strategy was designed to minimize bias and increase methodological accuracy. We pursued both automatic and manual approaches for sampling and further analysis of literature to increase validity and credibility of our results. Our sample was mainly obtained from the WoS scientific database as we were committed to including articles from high-quality journals in our analysis. However, we also performed an additional search through Google Scholar as we understand that the chosen database is limited, and asset management is a still-developing research category, thus ensuring representativeness of our sample.

Further, we shortly outline possible future research directions based on our findings, thus encouraging a more coherent development of research on strategic asset management. We believe that further studies have to focus on collecting more empirical evidence across industries; however, relying on the same understanding of asset management strategies and their role within the organization in order to ensure the possibility of comparison and generalization. While corporate-level strategies determine budget constraints, overall strategy, and policy regarding the asset portfolio, we assume that it is most important to conduct research aimed at the competitive and functional levels of strategic asset management. These levels are largely engaged in developing sustainable competitive advantages based on the assets and direct governance of the asset portfolio. Within these levels of strategy, exploring the link between strategic asset management and organizational performance seems to be a very important research direction as this is a largely underdeveloped area [13].

5. Conclusions

To the authors' best knowledge, this is the first attempt to reflect on the existing literature devoted precisely to strategic aspects of asset management. Through conducting a systematic literature review, we demonstrated that strategic asset management is an important, while still underdeveloped, area of research that received increased attention in recent years due to numerous factors challenging asset-intensive businesses. Despite the existing theoretical ambiguity and variety of approaches and interpretations from different communities of practice, our results support previous research and indicate that the accumulated experience can serve as a basis for further understanding the strategic nature of asset management within the whole organization and throughout all levels of decision-making.

Our key goal was to systematically review the existing research devoted to strategic asset management and explore the possibility to align asset management strategies with the overall organizational strategy according to different levels of management.

Thus, we contribute to the existing body of literature through (1) positioning strategic asset management as a distinct research category, (2) describing the nature of strategic asset management research in terms of epistemological orientations, and (3) confirming the possibility of aligning asset management strategies with the overall organizational strategy. We argue that explicit references to well-established strategic management theories and approaches will lead to the development of a more coherent body of literature on strategic asset management with higher methodological and theoretical consistency. We also suggest that business and functional level strategies are of particular interest for further studies that have to focus on the issues of developing sustainable competitive advantages and closely investigate the "strategizing" process within the "black box" of asset management strategy.

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Appendix A

Table A1. Snowballing Sample.

#	Snowballing Stages	References
1	Start set: 20 articles	[1,2,9,10,15,101–115]
2	1st iteration (backward snowballing): 21 articles	[28–30,34,42,44,45,48,116–128]
3	2nd iteration (forward snowballing): 26 articles	[4,11,13,14,33,35,68,78,117,129–144]
4	Second loop: 8 articles	[36,108,145–150]

Appendix B

Table A2. Contextualization of asset management strategy across different organizational levels.

Articles	Corporate	Competitive	Functional	Operational
Unit of Analysis	Contextualization of AM strategy			
Alegre, H. (2010) [49]	+ (global context, stakeholders' expectations)		+ (tactical planning)	+ (implementation of plans)
Anderson, Keleher & Smith (2008) [50]				+
Bakir & Raine (2018) [37]			+ (key performance indicators, strategic asset management program)	+ (field staff)
Baum & Vlok (2013) [38]	+ (senior sponsorship, motivation, supportive culture)		+ (decision networks, information network for maintenance planning)	
Beitelmal et al. (2017) [51]	+ (influence of external environment, long-term planning, stakeholders' satisfaction)		+ (KPIs, asset management policy and culture, organizational support, organizational structure)	+ (asset management processes)
Brown et al. (2014) [78]	+ (vision, mission & values, corporate governance, policy, objectives & strategy, external context, multi-agencies cooperation, sustainability management, allocation and prioritization of limited financial resources, leadership & change management)	+ (industry & market structure)	+ (asset life-cycle management, AM policy, objectives & strategy, evaluation of asset performance)	+ (service delivery, operational planning)
Caradot et al. (2017) [52]				+
Clements & Mancarella (2018) [46]				+
El-Akruti, Dwight & Zhang (2013) [39]		+ (product cost and price, quality and quantity, business performance and profit margin, competitive position, maintenance as key to competitive advantage)	+ (asset life cycle & supporting activities)	+ (asset performance)
El-Akruti, Kiridena & Dwight (2018) [3]	+ (corporate mission & goals, organizational change on response to external pressures)	+ (competitive demands & priorities)	+ (asset-related supporting activities)	+ (asset performance)
Geiss & Guder (2017, December) [53]				+
Godau & McGeoch (2016) [69]	+ (CEO and key stakeholders' involvement, communication & continuous improvement)		+ (asset management objectives, roles, functions & documentation, asset management maturity, asset life cycle, standardization)	+ (asset criticality & hierarchy, asset data)
Hanski et al. (2016) [70]	+ (stakeholders' expectations, sustainability issues, external environment)	+ (customer-driven approach to business)	+ (ISO 55000 guidelines adoption, AM risks, roles & responsibilities)	+ (asset data on criticality & failure, asset information management)
Herder & Wijnia, (2012) [15]	+ (resource allocation, external change & adaptation, public interests)		+ (systems approach, creating value from assets, asset design, risk management, agent-based modelling, optimization of AM process)	+
Hogan et al. (2011) [71]	+ (resource allocation, organizational change)	+ (higher quality and lower operational costs)	+ (maintenance planning & strategy from tactical point of view)	

Table A2. Cont.

Articles	Corporate	Competitive	Functional	Operational
Unit of Analysis	Contextualization of AM strategy			
Jolicoeur & Barrett (2005) [31]	+ (budget constraints, investment decisions, stakeholder involvement, long term planning)	+ (cost-effectiveness, market positioning)	+ (asset management planning & performance of assets, asset life cycle)	+ (service delivery, asset rationalization)
Joseph et al. (2018) [72]	+ (policies form regulators & investors, organizational culture and support)	+ (new product introduction to provide added value)	+ (choice of optimal asset management strategy, asset displacement decisions)	+ (asset utilization)
Kannapiran et al. (2008) [54]				+
Kauer & Sacher (2004) [55]	+ (acceptance of senior management)	+ (economic efficiency/cost-effectiveness)	+ (asset risk management, asset life cycle)	+ (asset inspection & servicing)
Khasnabis, Bartus & Ellis (2004) [56]	+ (limited funds distribution, long-term fleet planning)		+ (replacement vs. rebuilding programs)	+ (fleet data)
Komonen, Kortelainen & Rääkkönen (2006) [36]	+ (scenarios of strategic development, green-field, expansion & replacement investment decisions, strategic change & long-term perspective)	+ (market & industry structure, portfolio of competitive advantage: effectiveness/flexibility)	+ (asset life cycle management, maintaining and optimizing asset value, improving profit-making capability, choice of maintenance strategy, asset risk management)	+ (system and equipment level objectives & constraints)
Komonen, Kortelainen, & Rääkkönen (2012) [1]	+ (resource allocation & investment decisions, stakeholders' expectations, external pressures, shareholders' demands, values, visions, long-term objectives & strategy, portfolio management, decisions on mergers, disposals, outsourcing & production cooperation)	+ (competitive advantage & changing demand, industry structure, barriers to entry & sources of differentiation, resources & competencies development)	+ (asset life cycle management & optimization, optimal capacity, equipment effectiveness, reliability & flexibility, lower maintenance costs, asset criticality, improvement, replacement & maintenance programs)	+ (operation and maintenance)
Kortelainen, Happonen & Kinnunen (2016) [68]	+ (capital investment decisions, business objectives & performance, in-house or outsourcing decisions, co-operation with service providers, stakeholder management, requirements for sustainability & safety)		+ (asset life cycle management, asset portfolio, KPI)	+ (operational success factors)
Laue et al. (2014) [14]	+ (corporate governance, policy & strategy, stakeholder management, risk & sustainability, inter-organizational collaboration, regulatory pressures)		+ (asset governance, AM policy, strategy & plans, performance measurement & audit, AM capability & maturity)	+ (operations & maintenance, condition monitoring)
Liyanage (2012) [10]	+ (influence of stakeholders & external demands)	+ (resources & capabilities, creation of value, business climate)	+ (asset information management, integration of systems & interoperability of solutions, AM excellence & multidisciplinary approach, asset life cycle)	+ (provision of service)
Maletič et al. (2018) [13]	+ (sustainable development goals: economic, environmental, employee-related social performance, stakeholders' expectations)	+ (gaining competitive advantage, resources & capabilities)	+ (AM policy & strategy, risk management, performance assessment, lifecycle management, optimizing cost, performance & risk, continuous improvement)	

Table A2. Cont.

Articles	Unit of Analysis	Corporate	Competitive	Functional	Operational
		Contextualization of AM strategy			
Martin et al. (2015) [61]		+ (stakeholders' expectations, mobilization of limited resources, legislative & regulatory requirements)	+ (industry influence)	+ (AM plans, practices, policy and strategy, forecasting & modelling, proactive risk management)	+ (service level)
Mathieu et al. (2017, December) [62]		+ (regulatory pressures)	+ (high quality/low cost)	+ (balancing performance, risk and costs, asset life cycle, KPIs, asset manager as a tactical layer of decision-making)	+ (operational excellence, provision of services)
Matthews, Piratla & Koo (2016) [59]		+ (leadership, resources allocation, climate and risk, environmental pressures)		+ (reactive/proactive strategies)	+ (active condition assessment)
Ngo, Shah & Mishra (2018) [58]		+ (limited resources allocation)	+ (cost-effectiveness)	+ (decisions on purchase, replacement & rehabilitation of fleet)	+ (operations & maintenance to increase service life)
Ossai, Boswell & Davies (2014) [60]		+ (stakeholders' expectations)		+ (plant management, initiation of sustainable asset management programs, compliance with KPIs)	+ (operations & maintenance)
Park, S., Park, S.I., & Lee (2016) [63]		+ (regulatory pressures & limited budget allocation)		+ (AM policies, strategies, plans, register, life cycle assessment)	+ (operations, asset utilization)
Patidar, Soni, V.K., & Soni, P.K. (2017) [33]		+ (senior management support & continuous improvement)		+ (maintenance function, performances & manufacturing performance)	
Pidwerbesky, Hunt & Douglas (2007) [64]		+ (outsourcing vs. in-house, current and new business opportunities)	+ (client expectations)	+ (regional asset management network, communications, relationship management & procurement)	+ (regional maintenance managers)
Pinjala, Pintelon & Vereecke (2006) [44]		+ (in-house or outsourcing, organizational structure & design)	+ (competitive priorities/basis for competition: cost, quality, flexibility)	+ (maintenance strategy, maintenance policy & strategy, maintenance as a separate part of the primary activities within the value chain, performance measurement)	
Posavljak, Tighe & Godin (2013) [40]		+ (resource allocation, long-term planning of investments)	+ (minimal cost to the public)	+ (maximization of network performance, choice between routine maintenance, preservation & rehabilitation, life cycle cost analysis)	+ (maintenance)
Roshani & Filion (2014) [47]		+ (budget limitations)		+ (optimization of rehabilitation, optimal allocation of limited financial resources, choice of asset management strategy)	
Stimie & Vlok (2016) [32]		+ (strategic direction, organizational design, communication, change management)	+ (sustainable competitive advantage)	+ (AM systems, processes, practices, commitment)	
Suryani et al. (2015, March) [41]		+ (long-term financing decisions)		+ (maintenance and renewal strategies, network reliability)	+ (periodical maintenance and inspections)
Swanson (2001) [48]			+ (business performance, quality & productivity, cost reduction)	+ (choice of maintenance strategy, asset design, monitoring & analysis)	

Table A2. Cont.

Articles	Unit of Analysis	Contextualization of AM strategy			
		Corporate	Competitive	Functional	Operational
Szasz & MacDonald (2012) [65]		+ (reinvestment cycle)	+ (revenue generation, competitive pressure, expectation of business and financial performance)	+ (reliability and availability plans and risks, asset life cycle)	+ (condition monitoring, failure reporting)
Tafazzoli (2017, October) [66]		+ (resource allocation, decisions on infrastructure expansion, environmental pressures)	+ (revenue risks)	+ (policies and practices, balancing resources across assets, upgrading assets, continuous improvement, extending service-life)	+ (maintaining and operating, data collection)
Tranfield, Denyer & Burr (2004) [45]		+ (planning for capital investment, stakeholder's engagement, business objectives, capital investment, decisions on in-house/outsourcing)		+ (asset strategy, knowledge & monitoring, balancing risks, costs and performance throughout the life cycle of assets)	+ (service delivery)
Tsang (1998) [28]		+ (strategic objectives, budget constraints & resource allocation)	+ (business performance & core competence)	+ (maximizing asset utilization in terms of costs and outputs, performance measurement)	+ (service delivery & maintenance operation)
Tsang (2002) [30]		+ (organizational design & contracts)	+ (customer orientation, business performance)	+ (maintenance support, integration with operations, focus on performance, asset life cycle)	
Tsang, Jardine & Kolodny (1999) [29]		+ (mission & strategic objectives, in-house or outsourcing decisions)	+ (competitive environment & business performance)	+ (KPI, business process reengineering)	+ (operational efficiency)
Velmurugan & Dhingra (2015) [35]		+ (vision of the organization, adaptability to changes on the environment)	+ (business targets, customer needs, availability of resources for reaching strategic objectives)	+ (maintenance function, maintenance strategy selection and optimization)	+ (operating systems, maintenance performance measurement)
Wenzler (2005) [42]		+ (regulatory pressures, limited resource allocation)	+ (higher quality with lower costs, business capabilities, market structure & competition, commercial goals)	+ (keeping assets healthy and operational, replacement decisions, asset design, financial returns on assets, failure modelling)	+ (operation and maintenance, asset information quality, quality of service)
White, Too, E., & Too, L. (2010) [8]		+ (limited funding, globalization, stakeholder demands, overall performance, long term organizational goals, values, strategy & structure)	+ (returns to scale, monopolistic & regulated markets, added value, customer needs, competencies & capabilities for sustaining competitive advantage, focus on customers and accountability of results)	+ (performance of assets, optimal allocation of scarce resources, asset portfolio, AM goals, roles & responsibilities)	+ (operation)
Wijnia & de Croon (2019) [11]		+ (long-term development of asset base in terms of costs, performance and risk)		+ (life-cycle optimization, failure modelling, optimal strategy choice)	+ (asset risk and age profiles, asset data)
Yahaya et al. (2018) [43]					+
Yeung, Chu & NG (2015) [67]		+ (communications with stakeholders, authority, long term strategic plan & goals, change management, decisions on outsourcing)		+ (balancing risk & performance, optimizing life cycle cost in long term perspective, continuous improvement of AM system, AM practices, plans & policies, risk management)	+ (maintenance, asset database, operational procedures, control activities)
Yiu (2008) [34]		+ (make-or-buy decision, outsourcing/insourcing/co-sourcing)	+ (benchmarking)	+ (facilities management as market-firm decisions)	

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