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Project Management in Data Warehouse Implementations: A Literature Review

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ABSTRACT Project management (PM) is a vital part of any data warehouse (DWH) implementation due to its complexity, time constraints, size, high costs, and importance to business. To help achieve efficient PM, project managers require a source of reference that aggregates the previously acquired body of knowledge (BOK) and presents the discovered findings. Yet, no such resource currently exits. Furthermore, no evaluation of the existing BOK has been made, which obstructs its current understanding and hinders future enhancements in the field. The goal of this paper is to remove these gaps by conducting a systematic review of the literature. The review identified 33 relevant studies. Results show that the current literature mostly covers global considerations and research on DWH requirements analysis techniques and that only a small number of studies were conducted to assist project managers. The review method incorporated two research dimensions used to synthesize, interpret and present the findings: the *PMBOK® Guide*'s PM knowledge areas (PMKAs) and DWH stage. The majority of identified studies pertained to integration management, followed by scope management PMKAs. The biggest research gap was discovered for procurement management PMKA. The project initiation/planning DWH stage is most frequently analyzed in existing studies, followed by requirement analysis and database design. Findings from the identified studies are incorporated into a reference map in order to serve project managers as a reference point for additional guidance in their projects and an agenda for further research is provided for researchers looking to contribute to the field.

INDEX TERMS Agile, data warehouse, literature review, project management, PMBOK guide.

I. INTRODUCTION

Today, data warehouse (DWH), analytics and business intelligence (BI) stand for some of the most important information initiatives for companies [1], [2]. The continuous evolution of DWH implementation [3], the foundation for decision support systems [4]–[7], with new concepts such as data lakes [8], [9], big data [10]–[15], NoSQL technologies [16]–[19], and real-time streaming [20]–[23], is happening in an era characterized by persistently faster release cycles [24], [25] and constant product enhancements [26], [27]. DWH projects are mostly noted as large [28], time consuming [29], expensive [30]–[32], and change-sensitive [33] enterprise projects. Due to this specific nature of DWH implementations, they have shown high-failure-rate outcomes [28], [34]–[36], [S15]. Such results, in combination with the trends mentioned above, demonstrate a need for the effective management of these projects, which should be established alongside other factors required for successful DWH implementation [6], [37], [38], [S7], [S22].

For a long time, project management (PM) has been recognized to play an important management role in achieving project success [39]–[41]. The relationship between PM and project success has been investigated on multiple levels. For example, studies by Joslin and Müller investigated the relationship between project management methodology (PMM) and project success [42], [43]. Furthermore, the application of PM practices in projects has been found to increase project success [44]. The role of PM has also been analyzed in the context of DWH implementations. Throughout the literature, there are many examples of how PM contributed positively to DWH success [5], [30], [45]–[47]. There are also studies that show PM to be one of the key determinants of DWH infusion [S1] and one of the prerequisites for a successful DWH implementation [S3], [48]. Altogether, there is significant evidence of the need for PM in DWH implementations.

The role of project managers in DWH projects has also been analyzed. Authors such as Kimball [7, p. 409],

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Adelman and Moss [5, p. 11], and Reeves [31, p. 87] emphasize the importance of the project manager role in DWH projects. Moreover, Gardner advises that a DWH project is not a good place for a novice project manager [S2, p. 60]. Several authors argue that DWH project managers need to have a wider technical expertise and knowledge of the overall DWH process and technology in order to implement their projects successfully [49] and [S1], [S3], [S19]. In addition, project managers face many challenges in DWH implementations [5], [31], [49]. Some of the commonly encountered impediments are lack of a methodology or the use of a wrong method [6], resistance to DWH implementation [5], [31], [50], long implementation durations [29], and scope management and/or schedule management [5], [31], [50].

In order to achieve more effective PM in DWH projects, project managers need a systematized reference of knowledge that focuses on PM in DWH implementations. It is important to ensure that project managers have such a resource at their disposal when faced with future DWH projects. Today, to the best of my knowledge, there are no systematic literature reviews that explicitly cover and focus on the PM aspect of DWH implementations. This is a problem for the PM community since, in their search for primary literature that would help them manage their DWH projects more effectively, project managers would not find a clearly structured overview as to what PM techniques, methodologies and practices have been used, what problems project managers have faced, what lessons have been learned from other implementations, and/or what have been the most recommended management guidelines in DWH projects. Implications for project managers proposed in this study provide some practical guidelines for practitioners, which can lead to more effective PM and conclusively, reduce the reported high failure rates of DWH implementations.

In addition, there is no existing overview that evaluates the current body of knowledge (BOK) regarding PM in DWH. This study constitutes an important first step to assess, systematize, and better understand what is covered by past work. By understanding previous research, the strengths and weaknesses of the current state of the art in the field of PM in DWH can be determined. Furthermore, literature reviews can identify potential gaps in knowledge [51]. The results of this review are incorporated in an agenda for further research. Scholars looking to contribute to the area of PM in DWH are provided with guidelines that will help enhance the future BOK in PM in DWH.

Thus, the objectives of this literature review are to:

1. Systematically analyze the current literature in the field of PM in DWH and discover PM-related content,

2. Present the discovered studies, the PM-related content and the key findings in a format that is best suited for project managers and the DWH practitioner community.

In order to achieve the objectives of this study, the following primary research questions are asked:

PRQ1. What methodologies, practices, tools and techniques, capabilities profiles, and development practices are covered in the discovered literature?

PRQ2. How are findings from the discovered literature mapped to the PÌ Knowledge Areas (PMKAs) from *the PMBOK® Guide* (sixth edition) [52] and to the DWH stages[1] (the two research dimensions used in the review to better present the findings)?

In order to further assess the discovered literature, the following secondary research questions are asked:

SRQ1. How does the discovered literature address the common risks and challenges in DWH implementations?

SRQ2. To what extent are project managers presented as the primary readership of the discovered literature?

SRQ3. To what extent does the current literature provide empirical evidence?

SRQ4. What is the structure of the identified literature (publication type (journal article or conference proceedings), classification of the literature by paper type, and the age of the literature)?

The main contributions of this study to DWH project managers and practitioners are that:

1. it systematically reviews the current literature on PM in DWH and presents the discovered PM oriented methodologies, practices, tools and techniques, capabilities profiles, and development practices (PM-related content);

2. it shows how the discovered findings are mapped to the PMKAs from the *PMBOK® Guide* and to DWH stages, thereby providing project managers with a reference map of studies for potential guidance based on the relevant DWH stage of their projects. This should ultimately improve the way in which DWH projects are managed via project managers or other managers/practitioners and lead to more frequent achievement of project success in DWH projects in practice;

3. it summarizes the findings from existing academic research of relevance while presenting implications for project managers and DWH practitioners.

From the perspective of scholars and researchers interested in the topics of PM, DWH, and PM in DWH, this study will prove beneficial since:

1. it presents the first systematic literature review in this field and hence reveals the overall structure of the identified literature along with key research gaps; and

2. it proposes an agenda for future research, an important first step in understanding and then expanding PM knowledge.

The rest of this paper is organized as follows: *Section II Previous Work* – reviews related previous literature review; *Section III Review Method* – elaborates on the research model and the steps executed in retrieving the relevant studies for further analysis; *Section IV Findings* – presents the

[1] Stages or phases through which a typical DWH implementation goes through. For example, initiation stage, planning stage, Extract Transform Load (ETL) stage, etc. The research dimensions are elaborated in Section III, subsection E.

content from the studies resulting from the literature review; *Section V Discussion* – presents the quantitative and qualitative results tied to the primary and secondary research questions; *Section VI Limitations* – discusses the limitations of the used review method; *Section VII Proposed Agenda for Future Research* – proposes a research agenda based on the literature findings; and *Section VIII Conclusion* – discusses the implications of this literature review for practitioners and researchers.

II. PREVIOUS WORK

Today, there are a large number of studies that analyze PM in software development [53]–[55] and in information systems undertakings [56], [57]. However, there are known differences in DWH implementations compared with traditional software development from the perspective of timescales [49], [S18], resource requirements [S4], [31] and development/PM aspects [S5], [50]. In addition, in the context of PM, the field of software development, referring mostly to application software, has been researched more than DWH implementations. A simple query on Google Scholar for *project management in data warehouse* returned only 334,000 results, whereas a query for *project management in software development* returned 3,680,000 results – roughly 11 times more. A similar comparison of the two topics in Scopus and Web of Science index databases resulted in 24 and 70 times more search results related to software development PM, respectively. These findings clearly indicate that there are differences in the amount of available literature in the two fields. Keeping in mind that there are specifics in DWH implementations, in regard to traditional software development, this literature review was conducted with an objective to discover the current literature with a specific focus on PM in DWH implementations.

To the best of my knowledge, this study presents the first comprehensive literature review regarding PM in DWH projects. Nevertheless, it should be noted that there are several existing literature reviews that analyzed DWH implementations. However, these literature reviews do not focus on the PM aspect. A literature review by Krawatzecka and Dintera [58] identified studies regarding agile BI practices. In their definition of BI and literature search, the authors also included studies regarding DWH implementation. The main differentiation between this study and the literature review by Krawatzecka and Dintera is that the former concentrates more on the PM aspect of only DWH projects and consequently not BI projects, while the latter focuses more on identified agile practices and guidance for their selection. Baker and Canessa [59] conducted a review that focused on the design phase of the DWH; however, PM was not covered in the research. Chen *et al.* [60] conducted an exploratory study based on a literature review with the goal to identify factors of end-user satisfaction with DWH systems. However, there is no mention of PM in this study as well. The only mention of PM that was discovered in a literature review type of study was found in [S7], which is reviewed in this literature review. Regardless, [S7] focuses on DWH success factors, whereas this study is focused on PM in DWH.

III. REVIEW METHOD

With the goal to achieve the objectives of this study, the applied review method has some unique characteristics. First, the review method defines a set of inclusion criteria for the selection of the studies that are to be included in the review, and which leads to the identification of PM-related content in DWH projects, such as: methods, processes, tools, practices and techniques, capability profiles, and development practices that were used in DWH projects and that are PM oriented. By doing so, the focus on literature in the field of PM in DWH implementations is achieved. Second, the findings from the identified studies are presented in the context of the two research dimensions: (1) the PM knowledge areas (PMKAs) derived from the *PMBOK® Guide* [52] and (2) DWH stage. By examining the literature and framing the research results through a prism of the two research dimensions mentioned above, the findings from this study will allow DWH project managers and practitioners to focus on specific stages at which their DWH implementation is currently situated and then use the identified PM-related content as a guideline in their projects. Project managers will benefit from the presentation of the results in the form of the PMKAs from the *PMBOK® Guide* since they are familiar with its content and structure.

For this study, the review method is based on common proposals for the conduct of systematic literature reviews in information systems research [61] and in the software engineering domain [62], [63]. The stages of the review approach and steps taken to carry out the systematic literature review are illustrated in Figure 1. First, in the planning stage, the primary and secondary research questions and the motivations behind them are presented. Next, during the conducting stage, the search process is performed by searching through the selected electronic databases using the developed search strings. In the study selection step, studies are filtered based on the inclusion and exclusion criteria. In the data

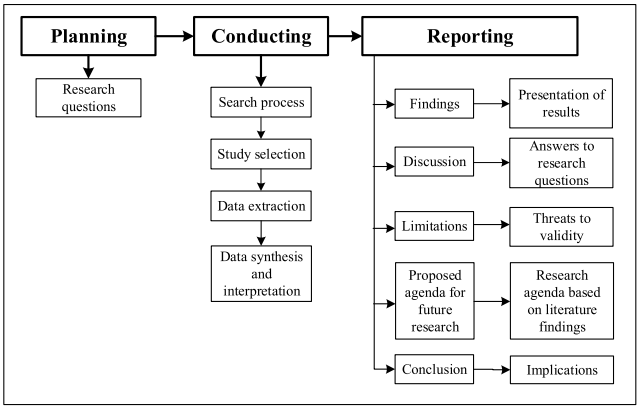

FIGURE 1. Review method stages and steps.

TABLE 1. Research questions and motivation.

Primary (PRQ) and secondary (SRQ) research question	Description and motivation
PRQ1. What methodologies, practices, tools and techniques, capabilities profiles, and development practices are covered in the discovered literature?	Following the main scope and objectives of this study, the idea is to gain a comprehensive understanding of the methodologies, practices, tools and techniques, capabilities profiles, and development practices that are used in DWH projects.
PRQ2. How are findings from the discovered literature mapped to the PM Knowledge areas (PMKAs) from *the PMBOK® Guide* and to the DWH stages?	Following the main scope and objectives of this study, the goal is to present the findings in a way familiar to project managers and to see what DWH stages are covered. By performing such a classification, we can see with more precision what areas are covered in the literature and what need additional research. In addition, DWH project managers and practitioners are provided with a reference map for additional guidance.
SRQ1. Does the discovered literature address the most common risks and challenges in DWH implementations?	The idea is to measure how beneficial the identified literature is for the PM and DWH practitioner community by checking whether it provides guidance for overcoming most common risks and challenges in DWH implementations.
SRQ2. To what extent are project managers presented as the primary readership of the discovered literature?	It is assumed that studies in which project managers are explicitly stated as the primary readership are of most relevance to the PM community, since to these studies, project managers can most easily relate. The goal is to identify these studies and to assess the literature through this prism.
SRQ3. To what extent does the current literature provide empirical evidence?	Empirical studies provide important evidence for the topic that is researched. The goal is to identify such studies and to assess the literature through this prism.
SRQ4. What is the structure of the identified literature (publication type (journal article or conference proceedings), classification of the literature by paper type, and the age of the literature)?	In order to better understand the current BOK, the identified literature's metadata (publication type, classification, and age) is analyzed.

extraction step, data needed to answer the research questions are extracted and presented in tabular forms. Finally, data are synthesized and interpreted in the context of the review method's two research dimensions. In the reporting stage, in the findings section data from the discovered studies are analyzed and interpreted. Answers to the defined research questions are provided in the Discussion section. The Limitation section elaborates on the recognized threats to the validity of the review. The Research Agenda section elaborates on the findings from this research in the context of potential future research questions and guidelines. In the Conclusion section, implications for project managers and DWH practitioners and scholars are presented.

A. RESEARCH QUESTIONS

Primary and secondary research questions as well as the motivation behind them, are elaborated in Table 1.

B. SEARCH PROCESS

Online databases were used as a source for gathering literature material. In the process of selecting the online databases, the aim was to cover the most relevant journals and conference proceedings in the fields of PM and DWH and hence the material that would contribute the most to this study. The selection process resulted in (1) publisher-focused online databases: ACM digital library, IEEE explore, SAGE Publications, Science Direct (Elsevier), and Emerald Insight; and (2) two major abstract and citation index databases: Scopus and Web of Science. All of the above online databases are suitable for systematic literature review-type research since they provide options to search via keywords, export, and manipulate the search data. The overall online database selection process is described below.

The first step in the online database selection was to create a list of the most relevant journals from the fields of DWH and PM, as these were viewed as the best places to look for literature that is suitable for this study. As a starting reference point for PM journals, a list found in [64] was used. Journals were then filtered by journal type (only academic journals were selected) and aim and scope (journals related to other industries, such as construction, were not considered). Additionally, PM journals that covered the fields of software development, information systems, and decision support systems were also selected due to their relevance. Selected journals were then checked and confirmed for their publishers and abstract/citation (index) databases (Scopus and Web of Science). A list of DWH journals found online [65] was used as a starting reference point. Similar to the method for PM journals, DWH journals were manually checked for their publisher and inclusion in an abstract and citation index database.

In turn, an additional step was conducted in order to broaden the list of relative journals and publishers and not to rely on a single reference. A sample of the PM and DWH journals identified above was put through a search on Scimago Journal Rankings (SJR) and a check was conducted for the journals' SJR subject areas and subject categories. SJR was chosen due to its connection with the Scopus database. All PM journals were categorized under *business management and accounting* for their subject area, and the majority of journals had *strategy and management* and *management of technology and innovation* for their subject categories.

DWH journals were found under the *decision systems* and *computer science* subject areas and *information systems and management* and *information systems* subject categories. SJR was then searched for most relevant journals in these subject areas and categories (only the Q1 and Q2 SJR quartile was filtered).[2] The goal here was to identify the top 5 publishers of the best ranked journals in the subject areas and categories mentioned above. The publishers identified at this stage were *Springer, Elsevier, Inderscience, Taylor & Francis, Emerald Group, IEEE, Kluwer, Sage, and Blackwell*.

Finally, the list of publishers indicated above was confirmed to be included in the Scopus database [66, p. 4] and, with the exception of *Inderscience,* in the Web of Science list of publishers [67]. Additionally, both Scopus and Web of Science were included as sources due to some specific differences in their coverage of journals in the area of social sciences and natural sciences and engineering [68]. In addition to Scopus and Web of Science, several publisher-specific online databases (ACM Digital Library, IEEE Explore, SAGE Publications, Science Direct (Elsevier), and Emerald Insight) were included in the search since (1) these provided additional content from most relevant publishers compared to Scopus and Web of Science and could hence contribute additional literature and (2) these were used in other systematic literature reviews in the areas of software engineering domain [62], [69]–[71], agile [72], [73], and project management [74].

The final list of online databases used for this literature review is presented below:

- ACM Digital Library;
- IEEE Explore;
- SAGE Publications;
- Science Direct;
- Springer Link;
- Emerald Insight;
- Web of Science Core Collection;
- Scopus.

Due to the number of electronic databases chosen and the selection of two large abstract and citation index databases (Web of Science Core Collection and Scopus) in the review method, snowballing technique was not used in this review.

Before the final set of search terms was determined, different variations were tested. For example, searching using the term *Pmbok* or by PMKAs limited the search results. Terms such as *business intelligence and decision support systems* did not result in studies that focused on DWH implementations. Finally, it was concluded that the terms *data warehouse/data warehousing* and *project management* produced the largest number of results and that the studies that resulted in this query have the strongest correlation with the study's objectives and hence, research dimensions. The term ''agile'' was included in the search since DWH projects apply both agile and process-oriented (plan-driven) practices [S4]. The same author, in their previous research [S5], conducted a qualitative analysis and found that agile aspects contribute significantly to the success of DWH initiatives and that agile practices should be used in combination with PM. Moreover, ''agile'' was included in the search because of the inclusion of agile practices in the latest version of PMI's *PMBOK® Guide* (sixth edition) [52] and in the PRINCE 2 methodology [75]. Finally, agile practices have a high impact on PM, particularly on people, processes, and projects [76]. This indicates the mutual connection between PM and agile principles.

The search was performed through full text and metadata searches using the terms delineated below. All terms were searched alongside with the Boolean operator ''OR''. The search terms used are presented below.

1. ''data warehouse'' AND ''project management''
2. ''data warehousing'' AND ''project management''
3. ''data warehouse'' AND ''agile''
4. ''data warehousing'' AND ''agile''

There were no limitations on the date range of the performed search. It should be noted that the initial search was performed in May 2019 and that in October 2020, online databases were checked for new additions.

C. STUDY SELECTION

Studies collected from the database search were included in the review if they provided examples or content that satisfied one or more of the following inclusion criteria, as described in Table 2: (1) methods, frameworks, or process guidelines for managing DWH implementations or specific segments of DWH implementations (for example requirement analysis); (2) tools, practices, techniques or models used in DWH projects, including references to agile practices, activities and techniques used; (3) capability profiles, i.e. recommended team member profiles, organizational charts, organizational

TABLE 2. Inclusion criteria.

Criterion	Criterion explanation	Orientation
1. Methods or process	Methodological or process guidelines for managing DWH implementations.	PM/PMKA
2. Tools, practices and techniques	Mentions of best practices used for solving specific problems. Included are showcases of how agile practices were used.	PM/PMKA
3. Capability profiles	Team member profiles, organizational charts, organizational prerequisites, different factors, prerequisites or specific activities that enhance the DWH process or have an impact on overall project success, including research models.	PM/PMKA
4. Development practices	Guidelines, checklists, or practices focused on the development process of the DWH rather than on the organizational modalities.	Technical/PMKA

[2] Available at https://www.scimagojr.com/journalrank.php

prerequisites, different factors, prerequisites or specific activities that enhance the DWH process or have an impact on overall project success; this criterion also includes research models that analyze potential factors that increase the likelihood of DWH success or enhance the general development and/or management process; and (4) best practices and methods for certain development activities that can also be beneficial to the project manager role or should be addressed by project managers. By reviewing the literature through the prism of theses inclusion criteria, PM-related content is identified.

Inclusion criteria 1, 2, and 3 are derived from the definition of PMM by Joslin and Müller [43]. PMM is interpreted as an entity consisting of the following parts: knowledge areas, methods, processes, tools and techniques, and capability profiles. These criteria are chosen due to the following reasons. First, inclusion criteria 1, 2, and 3 are elements of the PMM, which has been linked to project success [42], [43]. Second, in projects, the chosen PMM needs to be tailored to the specific project environment [77]–[79], including the organizational environment [S3] and development approach [S12]. Given the above statements and the findings that in practice, custom methodologies are applied to most DWH projects [S4], the findings from unique projects and situations (described in section IV of this study) will be beneficial to DWH project managers and practitioners on other projects. Finally, by analyzing studies resulting from this literature review through inclusion criteria 1, 2, and 3, PM-related content is categorized in order to achieve a better overview of what is discovered. This content can directly or indirectly be connected to the first research dimension, PMKAs, as explained below.

Methodological or process guidelines (inclusion criterion 1) can be interpreted as guidelines for tailoring, which is a common topic in the *PMBOK® Guide* and is mentioned in each PMKA. Furthermore, each PMKA is defined by its processes. However, the list of processes from the *PMBOK® Guide* should not be interpreted as a finite predefined list of PM processes, but rather should be tailored to specific projects [52, p. 22]. Identified processes or guidelines can hence be used by project managers and DWH practitioners in their projects. Tools, practices and techniques (inclusion criterion 2) are all part of the core definition of PMKAs [52, p. 23]. Capability profiles (inclusion criterion 3) can be connected to PMKAs through organizational process assets, which are inputs to the majority of processes, or through expert judgment, which is also used throughout the *PMBOK® Guide*. Inclusion criterion 3 is also analyzed by interpreting how specific roles from the project team contributed to the DWH project. Having the above in mind, inclusion criteria 1, 2, and 3 are mapped as PM/PMKA-oriented.

It is important to further elaborate on why inclusion criteria 3 and 4 are selected. Even though globally recognized PM bodies of knowledge such as PMI [52] and Prince 2 [80] do not cover technical roles and focus more on a generalization of roles, more focused literature on DWH PM [5], [31], [S23] includes descriptions and suggestions regarding specific project team member roles. Since DWH practitioners and authors mention the importance of technical skills for the project manager role [49], [S3], [S19], studies that described best practices and methods for technical activities were also included. Due to the specific nature of the inclusion criterion 4, it is mapped as technically oriented. However, the discovered development practices can also be mapped to specific PMKAs due to the context in which they are used. For example, one of the studies from this literature review mentions the importance of regression testing [S18]. Testing is mostly connected to the quality management PMKA in the *PMBOK® Guide*. However, in this study, the authors also discuss the importance of planning for these tests early in the project and provide additional timeline guidance, which indicates a link to the schedule management PMKA.

At the same time, studies were filtered out by using the exclusion criteria delineated in Table 3. (1) Studies with unrelated titles and/or inadequate abstracts, i.e., studies of unrelated topics, studies that focus on non-DWH related implementations, studies that describe the software tools used in DWH processes, or studies that showcase the benefits of DWH or BI implementation inside an organization. (2) Studies that are on the topic of DWH implementation but do not satisfy any of the inclusion criteria. (3) Book chapters regarding the topics of DWH PM and agile DWH, such as [5], [81]. These were excluded from the analysis since their content is too wide-ranging for the scope of this research. However, it is important to note that these books provide valuable knowledge in the area of DWH PM and are referenced in this study. (4) Studies that could not be accessed, viewed, or purchased via the web at the moment of the writing of this literature review.

TABLE 3. Exclusion criteria.

Criterion	Criterion explanation
1. Unrelated studies	Studies that are out of scope of this literature review. Studies that do not focus on DWH.
2. Lack of inclusion criteria	The study is on the topic of DWH implementations but does not contain any of the PM oriented inclusion criteria presented in Table 2.
3. Books and book chapters	The literature on DWH PM is out of the scope of this study since its context is too broad for the established research model.
4. Not accessible	Studies that could not be accessed via the Internet at the time of the review.

The search results from the individual sources were gathered in a single Excel document and analyzed further. The initial search from the above databases resulted in 1236 hits. After duplicate titles were removed, the initial search totaled 1145 unique studies. Following the study selection process, 33 studies were retained for detailed assessment. Throughout this paper, these studies are referenced from [S1] to [S33]. Appendix A contains the full bibliographic citations for the

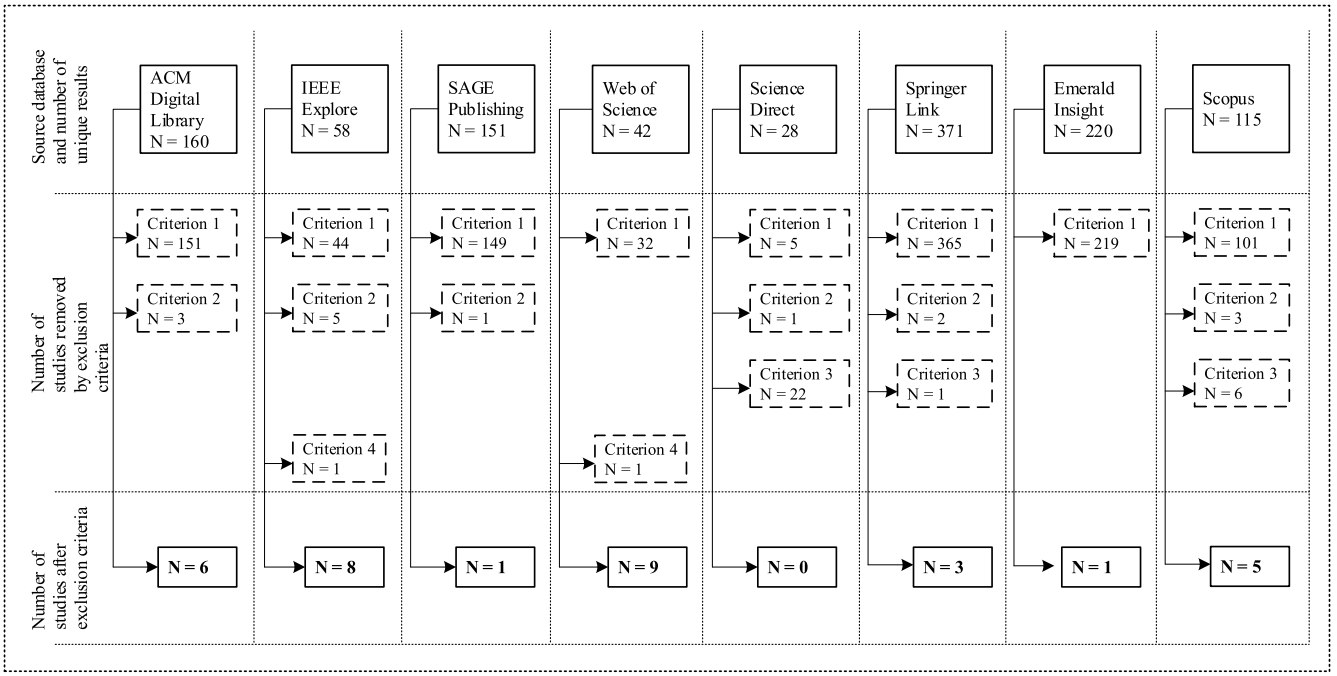

FIGURE 2. Research results per exclusion criteria.

selected studies. Figure 2 illustrates the number of search hits based on their database source and exclusion criteria applied.

D. DATA EXTRACTION

Data required to answer the primary research questions were extracted and are shown in Table 4. which is categorized based on the inclusion criteria Additional data, derived from the identified studies, including the metadata of the selected studies, was extracted and are presented in Table 5. Data from Table 5 are used to answer the defined secondary research questions.

E. DATA SYNTHESIS AND INTERPRETATION

In order to provide the answers to the primary research questions, the data extracted from the selected studies was then synthesized and interpreted in the context of the review method's two research dimension. Answers to secondary research questions are derived from both Tables 4 and 5.

The following text elaborates the literature review's two research dimensions and defines the premises that underline their selection. The two research dimensions are (1) the *PMBOK® Guide's* PM knowledge area (PMKA) and (2) DWH stage. These will be explained in separate subsections. The two dimensions are selected based on the following premises:

1. In PM research, *PMBOK® Guide's* PMKAs are often used as a framing concept to categorize research results.

2. Since DWH projects are dynamic ventures and are often characterized as a "never-ending" [82] or continual processes [49], the projects will continuously go through various stages.

1) RESEARCH DIMENSION ONE: PROJECT MANAGEMENT KNOWLEDGE AREA

To better explain why PMKA is selected as the first research dimension and hence premise number one, we first need to define the term PMKA. PMKAs are best described as the "*core technical subject matter of the PM profession*" [83]. However, in this paper, PMKAs are derived from the Project Management Institute's (PMI's) *PMBOK® Guide* [52]. In the *PMBOK® Guide,* the PMKA is defined as follows: "*A Knowledge Area is an identified area of project management defined by its knowledge requirements and described in terms of its component processes, practices, inputs, outputs, tools, and techniques*" [52, p. 23]. Accordingly, the PMKAs in this study are interpreted as PM knowledge categorized in specific areas, which is used to frame the results of the literature review.

PMBOK® Guide's PMKAs have been used in many PM-related research papers as a framing concept in order to provide some sort of a context for the study's research to which project managers are familiar with and can hence easily relate. For example, a set of studies [44], [84]–[86] investigates the extent of usage of PM practices in projects and their impact on project performance. In these studies, a list of practices was derived from the *PMBOK® Guide*, and the results were framed in different ways in accordance with the research theme in the context of the PMKAs. The study by Besner and Hobbs [87] grouped a large set of PM practices into specific *toolsets* and compared whether the newly defined toolsets match with the PMKAs and process groups from the *PMBOK® Guide*. It should be noted that the practices from Besner and Hobb's study were also partially

TABLE 4. Discovered PM-related content (Inclusion criterion 1: Methods and processes).

Study	Inclusion criterion 1: Methods and processes
S2	The proposed PMM methodology is based on the authors previous experience in DWH projects. It is heavily process oriented with three main stages: planning, design and implementation, and support and enhancement. The methodology is illustrated through step-based process chart, with brief explanations and objectives of the three steps. However, the proposed processes are not elaborated. In addition, there is no explanation as to when a specific step is considered complete. Therefore, the usability of the proposed methodology for project managers and practitioners is questionable.
S6	Proactive measures, comprising of a set of guidelines, are put in the context of the DWH project lifecycle and methodology proposed in S2. Each DWH stage is provided with a set of guidelines and high-level task descriptions. There is no in-depth explanation of the proposed guidelines, tasks and hence the "proactive measures" to insure proactive change management, therefore the implication usability of the proposed measures is presumably low.
S8	"4WD" is a DWH development methodology mostly influenced by agile software development principles, such as incremental and risk-based iterations, prototyping, user involvement, and light documentation. 4WD comprises of cycles that are interconnected. (1) data mart cycle: it defines and maintains the global DWH development plan. At the end of each iteration it designs and releases one data mart. (2) fact cycle: it is based on the modeling and implementation cycles. These cycles include the core of analysis, design, and implementation activities for delivering reports and applications concerning a single fact. Main tasks that occur in data mart and fact cycles are provided.
S12	The proposed methodological framework takes into consideration different design methods from the literature and problems practitioners faced in implementing DWH systems in higher education, such as complexity and uncertain requirements. The proposed framework is iterative and incremental. It consists of: (1) procedural steps - series of steps to be accomplished sequentially; (2) methods - the most suitable method for each procedural step; and (3) outcome - outcome from each procedural step after applying the proposed method. Some steps, such as the specification of business requirements ape described in more detail with proposed tasks and artifacts that should be developed. Others, not so much. Therefore, the framework's guidelines and usability are mostly related to the requirements specification phase.
S18	Testing activities explained in the study are put in the context of a reference data mart design methodology consisting of eight phases: requirement analysis, analysis and reconciliation, conceptual design, workload refinement, logical design, data staging design, physical design, and implementation. High-level diagram of steps involved in the overall process is provided. Testing activities are then further elaborated in the paper. However, not much is said about the specific methodology. It is primarily used in order to put the testing activities in to a lifecycle context.
S21 and S32	The proposed efficiency model is based on a premise that the increase in complexity should be followed with the change in the communication inside the project team. These changes in communication lead to an evolution of the terminology that is used. In S32 the model is upgraded with additional factors, such as cost, performance, and complexity. However, the proposed theoretical efficiency model is not really elaborated in much detail, even though it is backed up with evidence from multiple case studies. Therefore, the implication usability of the proposed model is presumably low.
S26 and S27	The described methodology contains four phases: Initialization, "as-is" analysis, "to-be" analysis, and modeling. Phases are composed of a set of activities, which are described in the paper. Steps inside the methodology are also illustrated. However, this methodology is not complete as, from what is stated in the paper, appropriate supporting documentation, techniques, and organization and information models still need to be defined. It is stated that the methodology has been partially tested in the real-life DWH projects. The proposed methodology is characterized as demand-driven.
S28	The proposed CADWE method (Computer aided Data warehouse Engineering) is just introduced in the conclusion of the study. Therefore, not a lot of detail is provided. CADWE is based on the findings from the study and it consists of four steps: Identifying strategic goals, expressing the objectives, discovering informational requirements, and defining the multidimensional schema. The study also lists the four identified types of requirements that should be addressed: strategic (related to the strategy of the organization), tactical (associated to a stakeholder's viewpoint), operational (related to required information), system (associated to targeted system). However, the proposed method is not elaborate in enough details therefore the usability for practitioners is presumably low.
S29	The proposed approach is focused on solving the semantic heterogeneity problem in current DWH development approaches. The approach is based on practices of agile software development and on the theory of common ground and grounding in communication. The paper also describes a template and design strategies for DWH projects. Finally, the overall approach is illustrated in the context of the *scrum-based* approach, with brief notation of supporting activities, meetings, milestones, stages, and outputs. The main limitation of the proposed approach, from the perspective of the project managers community is the heavy academic language in which the approach is described.
Study	**Inclusion criterion 2: Tools and techniques**
S8	Some of the practices and activities inside the "4WD" methodology are: prototyping, fact and data mart prioritization, explaining multidimensional modeling and conceptual design to end users ,in
S9	Most of the tools and techniques that were used in the paper were related to iteration planning and iterative delivery.
S10	Mathematical sprint planning optimization model. The model is based on concepts behind user stories prioritization and sprint composition and is explained through mathematical functions.
S11	ETL effort estimation model. The model is used for the estimation of ETL activities and is calculated by using Forward stepwise regression based on five predictor variables. These are: (1) Number of different types of sources used for data extraction, (2) The number of hierarchies representing levels of detail in the data, (3) The degree of documentation and suitability of source data for target systems, (4) Prior experience of developing similar ETL projects, and (5) Number of tables used for storing data.
S12	The technique for *Business processes prioritization* is described.
S14	The technique for automatic cost estimation with a modified analogies method is described.
S15	Earned value management technique.
S19	The following techniques are mentioned in the paper: • Responsibility and Accountability (RAM)
S24	Agile practices used: • Co-located teams, • Visual Project management, ○ Large poster of enterprise Data model was displayed in the co-located room. • Daily standups, • Kanban board, • Iterative requirement gathering, • Prune the product.
S25	Model for user story definition.

TABLE 4. *(Continued.)* **Discovered PM-related content (Inclusion criterion 1: Methods and processes).**

Study	Inclusion criterion 3: Capability profiles
S1	Effects on project success: Organizational support, PM process, Capability of DWH, and complexity of DWH are recognized as key organizational and innovation factors that influence the infusion of DWH.
S3	Effects on project success: Organizational prerequisites discovered as needed for successful DWH implementations: • Business-driven data warehousing initiative, • Executive sponsorship and commitment, • Funding commitment (budgeted and unexpected) based on realistically managed expectations, • Project team with access to cross-functional project management and implementation experience, • Knowledge of DW compatibility with existing systems, • Hardware/software proof of concept.
S4	Effects on project success: Agile factors are discovered as more significant in achieving DWH project success than plan-driven.
S5	Research on the application of agile in DWH: Business value, agile development, shared understanding, project management, technological capability, top management commitment, complexity, organizational culture.
S7	Research on DWH implementation success: In the study implementation success was presented as a group consisting of: organizational, project and technical success factors. Organizational implementation success: • Management support, • Resources (money, people, and time), • User participation. Project implementation success: • Resources (money, people, and time), • Team skills, • User participation. Technical implementation success: • Source systems (quality of the source system's data), • Development technology (hardware, software, methods, and programs used in completing a project).
S13	The following project tasks are mentioned as required for a successful enterprise-wide DWH implementation. • End-user support, • Service level agreements and data refresh requirements.
S16	Research on the importance of metadata management and its usefulness for DWH practitioners
S17	Emphasis on the importance of metadata management in DWH projects
S19	Innovations used during the design, development and testing phase and for team dynamics are provided. These are a form of a key lessons learned. In addition, an insight into the project team environment and organized meetings is provided.
S20	Effects of joint IT Competence (IT savvy business users and IS users) and partnership led implementation on end-user satisfaction with the implemented information system.
S22	Research on the risk management and main risk areas in DWH projects

S23	The following PM "what and how" are described in this study:
	• Project evaluation: Risk assessment:
	  ○ Initial Risk identification, categorization, and prioritization
	• Project initiation:
	  ○ Staffing - Organizational structure with the following roles: (Planning board, project board, Project team, Key stakeholders, and Key resources)
	  ○ Scope management - starting small with a pilot project and incremental development of data marts
	• Project execution
	  ○ Development of the target architecture
	  ○ Implementation strategy - Incremental approach (creating the simplest and most beneficial data marts first)
	  ○ Project support process - eight "critical performance areas" were identified (such as data integrity and metadata management, etc.)
	• Project closure - Next steps were planned based on the lessons learned from the pilot stage

S24	The following project team is mentioned: • Client Database administrators, • Data Architect Lead, • Reporting Solution Lead, • ETL lead, • Developers, • Subject matter experts,

TABLE 4. *(Continued.)* **Discovered PM-related content (Inclusion criterion 1: Methods and processes).**

Study	Inclusion Criterion 4: Development practices
S2	DWH metadata management.
S3	Organizational prerequisites discovered as needed for successful DWH implementations: • Attention to source data quality, • Flexible enterprise data model, • Data stewardship, • Long term plan for automated data extraction methods / tools,
S8	Some development activities and principles related to the proposed "4WD" approach are described. These are: • Bus matrix document, • Fact design documents, • Component reuse (conformed hierarchies, library hierarchies, predefined ETL building blocks, and analysis templates).
S13	The following development practices are described in the study: • Source system identification • Data quality planning • Data model design • Extract, transform, and load (ETL) tool selection • Relational database software and platform selection • Data transport • Data conversion • Reconciliation process • Purge and archive planning
S16	DWH metadata management
S18	Following DWH tests are elaborated: • Conceptual and logical shema tests, • ETL test, • Database tests, • Front-end tests, • Regression tests.
S24	The following more technical practices are described: • Iterative DWH requirements gathering, • Database Re-factoring, • Database Continues integration, • Data model version control
S30	The paper provides an analysis of the following approaches: • Normalized DWH (E-R modeling) (Third normal form), • Dimensional Data Modeling, • Data vault modeling, • Anchor Data modeling.
S31	Anchor modeling technique

derived from the *PMBOK® Guide*. The study conducted by Oun *et al.* examined the relationship between enterprise-wide PMKAs and the PMKAs found in the *PMBOK® Guide* [88]. Finally, the study by Zwikael investigated the importance of the *PMBOK® Guide's* PMKAs on project success during the project planning phase [89]. *PMBOK® Guide's* PMKAs can also be found as a framing concept in a systematic literature review paper [54].

The studies mentioned above show that framing results in PM-oriented studies through PMKAs is a familiar concept and it is therefore used in this study as well. In addition, the *PMBOK® Guide's* PMKAs have also been chosen due to the worldwide recognition of the PMI's framework presented in the *PMBOK® Guide*.

Even though PMI states that specific projects may require additional PMKAs [52, p. 553], for this study, the list provided in the *PMBOK® Guide* serves as a foundation. The PMKAs are the following: (1) integration management, (2) scope management, (3) schedule management, (4) cost management, (5) quality management, (6) resource management, (7) communication management, (8) risk management, (9) procurement management, and (10) stakeholder management.

Data synthesis and interpretation in the context of the PMKA research dimension is based on the descriptions, inputs and outputs, processes, and techniques of PMKAs found in the *PMBOK® Guide*. The identified PM-related content and the main selected study's findings were mapped

TABLE 5. Findings regarding the primary readership, empirical evidence, and the discovered studies' metadata.

Study	Project managers are the primary readership	Empirical evidence	Year published	Literature type	Literature classification
S1	No	Yes	2008	Journal article	Original research
S2	Yes	No	1981	Journal article	Short report
S3	No	Yes	2000	Journal article	Short report
S4	No	Yes	2018	Journal article	Original research
S5	No	No	2017	Journal article	Original research, Case study
S6	No	No	2006	Conference proceeding	Short report
S7	No	Yes	2001	Journal article	Original research
S8	No	No	2011	Conference proceeding	Methodology
S9	No	No	2011	Conference proceeding	Case study
S10	No	No	2012	Conference proceeding	Methodology
S11	No	Yes	2015	Conference proceeding	Methodology, Original research
S12	No	Yes	2015	Journal article	Methodology, Case study
S13	No	No	2005	Journal article	Short report
S14	No	Yes	2018	Conference proceeding	Methodology
S15	Yes	No	2006	Journal article	Case study
S16	No	Yes	2007	Journal article	Short report, Original research
S17	No	No	1998	Journal article	Short report
S18	Yes	No	2009	Conference proceeding	Methodology
S19	Yes	No	2017	Journal article	Short report
S20	No	Yes	2009	Journal article	Original research
S21	Yes	No	2009	Conference proceeding	Methodology
S22	Yes	No	2010	Conference proceeding	Short report
S23	Yes	No	2002	Journal article	Case study
S24	No	No	2012	Conference proceeding	Case study, Short report
S25	No	No	2017	Conference proceeding	Methodology
S26	Yes	No	2003	Conference proceeding	Methodology
S27	Yes	No	2004	Conference proceeding	Original research
S28	No	No	2009	Conference proceeding	Case study
S29	No	Yes	2017	Journal article	Methodology, Original research
S30	No	No	2012	Conference proceeding	Short report
S31	No	No	2010	Journal article	Methodology
S32	Yes	No	2009	Conference proceeding	Methodology
S33	Yes	No	2008	Conference proceeding	Case study

to a specific PMKA appropriately. It is important to note here that specific PM-related content can be connected to one or more PMKAs. For example, the earned value method can be used for both schedule and cost tracking purposes. Therefore, the earned value method can be analyzed from the perspective of both the cost and the schedule management PMKAs.

2) RESEARCH DIMENSION TWO: DWH STAGE

From the perspective of DWH implementations, success factors can be defined as a set of factors that, when addressed appropriately, will have a positive impact on the success of a project [6]. For example, one of the commonly recognized success factors is the need to have a business-oriented DWH and that there should be strong higher management support for the project [6], [31], [50], [90]. On the other hand, a DWH project is a dynamic venture and is often characterized as a never-ending [82] or continual process [49] due to persistent user requests for new data and/or information. Hence, the DWH will often go back and forth through specific stages based on the scope of the implementation.

Taking into consideration the importance of recognizing and addressing DWH project success factors, their influence during different project stages, and the ongoing nature of all DWH implementations, the second premise is important in order to better understand how and when to use specific PM elements. Furthermore, analyzing studies through the prism of DWH stages, specific domain knowledge is identified, which can further enhance expertise coordination skills of project managers [91].

The DWH stage refers to the stages through which a typical DWH implementation needs to go through. Even though there are several stages and life cycles proposed in the literature [92]–[95] and [S2], [S8], with respect to the stages presented by Kimball [7] and Inmon [96], for the purpose of this study, a generalization of DWH stages is created based on the high-level representation of a DWH project plan template by Adelman [5]. The stages presented in [5] are selected because they are presented as a guide for a project plan for project managers. The stages used in this study are thus the following: (1) project initiation/planning, (2) requirement analysis, (3) database design, (4) extract transform load (ETL) design, (5) query/reporting development, and (6) production usage and maintenance. As recommended in [5], the stages above should not be viewed as stages in a waterfall-like model but rather as stages in a phase or iteration that are bound to be repeated in subsequent phases or iterations.

It should also be noted that, in general, based on study titles and abstracts, it is difficult for readers to see whether any particular study is addressing a specific DWH stage or is providing general remarks. This causes difficulties for the interested readership to narrow down the studies that may help them in their current projects. During data synthesis and interpretation, from the perspective of the second research dimension, all of the papers were matched to one or more DWH stages based on the overall context in which the paper was written. Papers that were written in a more general context or were referenced to the overall DWH implementation were mapped to the project initiation or planning DWH stage, as presented in section IV-A.

To summarize, by including the two research dimensions, the presentation of findings is categorized as follows: (1) through well-familiar PM terms and concepts (PMKAs) and (2) in a way that would give DWH project managers and practitioners an opportunity to cross-check the discovered PM-related content and the main study's findings in the context of the DWH stage in which their projects are situated at that moment. In addition, since literature reviews help reveal potential research gaps [51], these will be revealed more precisely.

IV. FINDINGS

In this section, the results from the data synthesis and interpretation step are presented in the form of the main findings and implications from the selected studies. This section is organized and grouped by DWH stages in order to simplify their overview (from A. Project initiation/planning to F. Production usage and maintenance). It should be noted that several studies cover more than one DWH stage.

With the aim to clearly display mappings to the first research dimension, that is, the findings against the PMKAs, subsections of this chapter are further structured in PMKAs, starting from integration management and ending with stakeholder management. Only those PMKAs that are connected with a specific DWH stage are included.

A. PROJECT INITIATION/PLANNING

1) INTEGRATION MANAGEMENT

The biggest number of studies (11 studies) identified in this literature review are mapped to the integration management PMKA and project initiation/planning DWH stage. The studies identified in this area can be mapped into one of the following categories: (1) studies that address global considerations for DWH projects [S1], [S3], [S7], [S13], [S23]; (2) studies that analyze the application of agile in DWH projects [S4], [S5], [S6], [S9]; and (3) studies that describe a specific methodology for managing and developing a DWH [S2], [S8].

Studies marked under global considerations provide useful considerations and focus points for successful implementations. These should be considered during project initiation or initial planning stages. Methodologies discovered are described on a high level and can provide overall direction for project managers when developing their own PMM. However, not enough details are provided in order to fully understand all the mentioned activities and processes. The identified research on the application of agile in DWH is heterogenous. It is evident that there is room for agile practices and that they contribute to achieving DWH success, however not enough focused research is present.

In the context of the integration management PMKA, the findings from all 11 studies described in this area can be viewed as an *enterprise environmental factor*, i.e., the PM BOK from specific industries that should be incorporated into the PM plan [52, p. 84]. Furthermore, the results and key messages from these studies can be considered by project managers when tailoring the project integration management processes [52, p. 74]. However, additional connections with the PMKAs are identified and are described in the following text, along with the main contributions from the studies identified in this literature review.

The study by Ramamurthy *et al.* examined the key determinants that influence the infusion of DWH throughout an enterprise [S1]. Specifically, the authors conducted a field study of 117 companies from two states in the U.S., through which they discovered that organizational support and commitment, compatibility with a firm's work, complexity, and the quality of the PM process all have a statistically significant influence on DWH infusion. Interestingly, the authors state that the described PM process can serve as a mediator for improving the business-IT relationship.

Studies that address global considerations for DWH projects:

Similar to [S1], Sammon and Finnegan presented organizational prerequisites that they state are needed for a successful DWH implementation [S3]. The authors adopted a case study approach and analyzed data from four major companies in the field of DWH implementation. The result was a list of 10 key prerequisites that a company should investigate prior to starting any DWH project. Among other prerequisites, such as pursuing a business-driven DWH, having support from senior management, and focusing on creating a flexible DWH, Sammon and Finnegan point out that organizations need to have strong PM and implementation skills. The authors state that this is needed due to the specific requirements of various business units across the organization. The findings from this study are derived from large enterprises and large DWH projects which may benefit project managers involved on such projects. However, not much elaborations are provided.

In a similar fashion, Solomon provided a list of ten project tasks that are key in order to avoid failure in enterprise-level DWH initiatives [S13]. The author also mentioned the importance of service-level agreements and how aspects such as the mandated arrival time, refresh type, frequency of data, and maintenance criteria should be addressed before the design stage. Finally, Solomon states that the success of the DWH initiative will be determined by the following factors: level of data access, timeliness and quality of the data delivered, and business user training. Additionally, Solomon describes several project tasks that are more technically related, such as source system identification, data model design, ETL tool selection, relational database software and platform selection.

Comparable findings are also presented in [S23]. In this study, Shin described some general considerations for DWH projects, which were derived upon his experience and interviews with the appointed project manager. Some of the key findings are related to the importance of developing processes that underline business and end user engagement and top management support. Furthermore, Shin provided lessons learned in the context of starting with small data marts in order to minimize the potential impacts of project failure. Finally, Shin provides an overview of the development approach and DWH architecture used in the project.

Wixom and Watson developed a research model in order to investigate the critical success factors for DWH implementations [S7]. The research model investigated DWH implementations from the perspectives of (1) implementation success, measured by organizational, project, and technical implementation success, and (2) information system success, measured by data quality and system quality. The results indicate that higher levels of team skills, user participation, and resources (human, financial, and time) are associated with project implementation success.

The five studies presented above also address key stakeholders and their roles in and influences on DWH projects. In particular, [S1] mentions the importance of organizational support. [S3] describes three prerequisites for a successful DWH implementation in the context of required stakeholders: (1) a business-driven DWH initiative, (2) executive sponsorship and commitment, and (3) a project team with access to cross-functional project management and implementation experience. [S7] lists management support, user participation, and a high level of team skills as factors that influence DWH project success. [S13] mentions end-user support and user training. [S23] emphasizes the importance of active involvement of business units, end users, and top management support. According to the *PMBOK® Guide*, the key stakeholders should be identified as soon as possible. This action is performed during the *develop project charter* process [52, p. 81].

Studies that analyze the application of agile in DWH projects:

The next two studies [S4], [S5] come from the same author – D. Batra. These studies are focused on the application of agile in DWH projects. First, based upon the grounded theory approach, Batra conducted interviews with DWH practitioners and investigated their experience with DWH development and the use of agile values and principles in their projects [S5]. The study identified 8 categories and additional subcategories, which Barta then converted into a proposed research framework. PM was identified as one of the key categories in the study. Contracting, scope management, expectation management, and documentation were also identified as PM subcategories. One of the study's main conclusions was the proposal to harmonize the use of agile practices with PM in order to achieve business value, through DWH. Additionally, study respondents stated that in large DWH projects, PM is a key factor that can also be used to mitigate the risks of agile development. These findings can be of special interest to project managers when considering how to integrate agile in to their PMM.

The framework developed in [S5] was then, with small alterations, tested in Batra's later study [S4]. In [S4], Batra developed a research model that analyzed the effects of agile values (values from the agile manifesto [97]) and plan-driven aspects (scope creep, expectations management, contracts, controls, and risk management) on project success (budget, schedule, quality, customer requirements, and decision making). The results showed that agile factors contribute more to project success than plan-driven factors.

In [S6], Li focused on the change management aspect of DWH implementation. He advocates a proactive approach to DWH change management, which also enhances the agility of the DWH. The main contribution of this study is a presented framework with practices that should be implemented throughout the DWH lifecycle in order to proactively address occurring changes in the business and hence keep the DWH beneficial for end users. This study proposes an interesting topic for project managers, which should be addressed at the early stages of the project with the team. However, the study lacks more detail elaborations on the specific steps to implement the suggested actions.

Goede examined the application of agile approaches in general and Scrum in particular to a DWH development project performed by several student groups [S9]. The study results show that overall, students found agile principles suitable for DWH implementations. Some of the challenges that students faced in their projects were related to defining the first increment and change management since the end users could better clarify and define their requests only once they saw the actual outputs. Teams also reported that they lacked some technical guidance from the agile approaches they have used. Interestingly, three teams reported that they should have spent less time on planning in the beginning since ''*everything changed from their initial plans*''. Implications from this study are limited since it is based on student-based projects.

The *PMBOK® Guide* addresses the agile approach in the integration management PMKA by stating that agile and iterative practices should be considered when developing the PMM [52, p. 73,74]. Therefore, the results from the studies that address the application of agile in DWH projects found in this area [S4], [S5], [S6], [S9] can be used as a reference point when developing the PMM. Furthermore, the focus of [S9] is on the proactive change management, which should also be considered not only when tailoring the project integration management processes [52, p. 74] but also as a part of the PM plan in the form of the *change management plan* [52, p. 88].

Studies that describe a specific methodology for managing and developing a DWH:

Gardner described how project managers should manage DWH projects and specified a PMM [S2]. The proposed PMM consists of three steps: planning, design and implementation, and support and enhancement. In his study, Gardner describes the three-step PMM and points out that it should be iterative and that business requirements change over time, meaning that the DWH should be flexible and scalable, allowing it to correspond quickly to new business requests. Gardner proposes that the presented PMM be considered while defining the DWH project approach. This study was written by a veteran author in the field however, there is not much elaboration on what is suggested.

Golfarelli *et al.* proposed a DWH design methodology named ''4WD'' [S8]. The 4WD methodology is based on the following principles: incremental and risk-based iterations, prototyping, user involvement, component reuse, formal and light documentation, and automated schema transformation. The methodology is built on four iteration cycles with lightly described and defined activities, releases, and output documents. Guidelines for data marts and fact prioritization are also presented, such as giving priority to data marts that have a well-structured and familiar source, postponing data marts with unclear requirements, and giving priority to facts that include main business hierarchies and require the most complex ETL processes. Just as in [S2] it would be difficult to develop a PMM based on these studies alone since more detailed elaborations are needed. However, these studies can provide some valuable guiding points.

In the context of PMKAs, studies [S2] and [S8] provided methodologies for developing and managing DWH projects. In accordance with the *PMBOK® Guide*, the project lifecycle, development approach and management review selection should be defined during the *develop project management plan* process [52, p. 88]. The proposed methodologies from these studies can be used not only by project managers when developing the PM plan but also as inputs when defining the PMM for the DWH project.

All of the studies from this area relate to the project initiation/planning DWH stage. For example, studies classified under the category of global considerations [S1], [S3], [S7], [S13], [S23] are described in an overall context, and their content can be attributed to DWH implementations in general. These studies should therefore be considered in the beginning of the project alongside other DWH key success factors [5], [6] [31], [50], [90], [98]. The agile practices and approaches found in [S4], [S5], [S6], [S9] should also be considered during the initial stages of the project when the overall project approach is being defined. Likewise, the proposed methodologies from [S2], [S8] would most likely be considered at the beginning of the project, i.e., during the project initiation/planning stage.

2) SCHEDULE MANAGEMENT

Two studies from the review are mapped to the schedule management and project initiation/planning stage [S10] and [S13]. Findings from [S13] are most beneficial to project managers since key project tasks, which should be planned for, are provided. Findings from [S10] are of specific value to practitioners that are looking to optimize they are planning their sprints.

In [S10], Golfarelli *et al.* describe a mathematical model for optimizing sprint planning in DWH implementations. The proposed model was created with the goal to maximize the delivered business value and takes into consideration factors such as team estimates, risks, the degree of correlation and constraints between user stories, and sprint capacity. The authors state that the model was tested in a real-world DWH project and provide the results from their experiment. Faster sprint plan creation via software tools, better risk handling, more realistic and feasible outputs, and the ability to better address the dependencies between the user stories were considered improvements over manually developed models. The practical application of the first study [S10] is limited since the proposed model is based on the mathematical and statistical formulations and it also requires a software tool to enable it. In the context of the schedule management PMKA, the proposed technique can be used by teams that are performing iterative scheduling [52, p. 177]. Techniques that will be used for scheduling, i.e., the scheduling methodology, should be established in the *schedule management plan* [52, p. 181].

The study by Solomon [S13] provides guidelines that should be accounted for when creating the project timeline. The author provides advice on planning for an activity,

performed in cooperation between IT and business, of profiling the data quality of source systems from which data will be migrated to the DWH. Solomon also mentions how data accuracy problems from the source systems will be transferred to the DWH if not addressed in the source system or in the ETL process. Later, Solomon mentions the task of reconciliation where, once the system is in production, the end users will start to compare new reports to reports from old systems. The author states that this process can delay the going-live date of the new DWH system if not addressed accordingly. Project managers should plan for this time but should also avoid comparing the new DWH outputs to the old outputs, which had defects to begin with. An additional project task that should be taken in account is the time that takes for the initial load of data to be imported into the DWH and verified. In the context of the schedule management PMKA, suggestions from this study can be viewed as *expert judgment*, which is used as a tool and technique throughout the schedule management PMKA [52, p. 174]. More specifically, the suggestions for creating the project timeline can be most beneficial during the *define activities*, *sequence activities,* and *estimate activity durations* processes [52, pp. 183, 187, 195].

3) COST MANAGEMENT

Two studies from the review are mapped to the cost management and project initiation/planning stage [S14] and [S15]. The only aspects of cost management that have been covered are: an example of using a cost estimation technique [S14] and cost tracking via the earned value management (EVM) technique.

In [S14], Pratama and Rasywir implemented a custom estimate method in order to estimate the cost of building a data warehouse [S14]. The method was based on an analysis of various financial data categories, such as project costs (traveling, reporting, meetings, and presentations), job payment lists, software licenses, and external components. The proposed method takes into consideration several factors, including the complexity of the project in order to reach a baseline estimation, value of software development, and programming effort, which is expressed in lines of code per functional area. The authors implemented their estimation method on one of their DWH projects. Interestingly, the results indicate that the price estimated with their proposed method was different from the actual project price that is offered by vendors in the field. The actual project cost was more than 50% less than the price estimated with their method. However, generalization of the study's results is limited since the study was conducted on only one project in India's market. In the context of mapping with the PMKA dimension, this estimation technique can be viewed as *expert judgment* from previous similar projects and the industry and application area regarding cost estimation and budgeting [52, p. 237]. Furthermore, the technique proposed in this study is based on analogous estimating, which is a technique that can be used when estimating costs [52, p. 244]. Project managers can use this technique when evaluating different cost estimation techniques and choosing the most appropriate for their project.

Gowan *et al.* described how earned value management (EVM) can be used to better justify and track cost and schedule variances in a DWH project [S15]. The authors outline certain prerequisites and best practices before EVM can be used on a DWH project, such as specifying different labor rates, linking hours spent with cost centers and budgets, and setting time and cost limits on tasks. They also recommend clearly stating out the rules for replanning or adding new tasks. Since new tasks may appear or some tasks may be performed later in the stage, if the current budget is not expandable, project managers need to reduce the planned hours from other planned tasks in order to achieve the ultimate objectives. The study also presents some of the benefits, challenges and solutions to using EVM in a DWH implementation, including inexperienced project planners and using EVM for only labor budgets. The topic of EVM is covered in the *PMBOK® Guide* in the *control costs process* [52, p. 261]. Recommendations from this study should be considered as *expert judgment* in the context of conducting EVM [52, p. 260] and should be reviewed by project managers that use EVM in DWH projects.

4) QUALITY MANAGEMENT

Three studies from the review are mapped to the quality management and project initiation/planning stage. The studies by Foshay *et al.* [S16] and Watson and Haley [S17] comment on the importance of metadata in DWH environments, whereas Golfarelli and Rizzi [S18] address the topic of testing in DWH projects. Overall, the findings highlight testing and metadata especially as important aspects that should be addressed by project managers.

In the context of the first research dimension, all three studies identified in this area are mapped to the project quality management PMKA since the processes from this PMKA address product quality requirements required to meet stakeholders' objectives [52, p. 271]. Furthermore, the findings from these studies can be seen as *expert judgment* [52, p. 281] or industry standards and best practices in DWH projects and should hence be considered when tailoring the quality management processes [52, p. 276]. Finally, all quality requirements and actions that will be taken in order to demonstrate compliance with these requirements should be identified during the *plan quality management process* [52, p. 277].

Foshay *et al.* analyzed data from two online surveys directed at DWH practitioners and end users, with the goal to analyze the role of end-user metadata in DWH projects [S16]. The study results indicate that both DWH practitioners and end users find metadata important and useful. However, practitioners find definitional metadata (meaning of the data in the DWH) to be the most useful, whereas end users find quality metadata (information about the refresh time, accuracy, validity, and completeness of data in the DWH) as the most useful. The authors conclude that metadata is found to have an important factor in influencing whether users will

develop a positive attitude towards the DWH. The authors advocate that project managers should take into consideration the findings while planning support and training programs for new and inexperienced DWH users. Interestingly, the findings also show that DWH practitioners know that the quality of the metadata delivered to the end users is not to their liking.

In [S17], Watson and Haley summarized findings from their several-years-long research program. The authors state that one of the primary reasons for implementing the DWH is to improve the quality of information in the organization. Having that in mind, they list metadata management as one of the main implementation challenges in DWH projects. Furthermore, they state that metadata are key for understanding the built DWH system. They elaborate on this by saying that end users rely heavily on metadata when using the system. In contrast, users without this type of information refrain from using the DWH or include other colleagues from IT to retrieve information for them.

As stated in the *PMBOK® Guide*, customer satisfaction, which can be expressed as a combination of conformance to requirements and fitness to use the product, is one of the factors that should be addressed when considering project quality management [52, p. 275]. The two studies above [S16], [S17] explain this relationship by investigating different effects that metadata management has on end users' conformance to the developed DWH systems.

In [S18], Golfarelli and Rizzi proposed a framework for testing DWH systems. In their study, the authors emphasize the importance of testing in DWH projects, especially the importance of the data quality, which they point out is one of the main areas of DWH testing. They mention regression testing, back-end (ETL), and front-end (OLAP and reporting) testing as some of the most important tests for DWH systems. The study also contains descriptions of specific activities for testing: conceptual schema, logical schema, ETL procedures, database, and front end. The proposed framework for DWH testing also covers different roles involved in the process of testing and steps for all testing activities. Finally, Golfarelli and Rizzi suggest project managers should use this information in the planning phase and when planning for DWH testing. They underline creating test plans in early project stages as one of the key success factors for DWH. In the *PMBOK® Guide*, product testing is viewed as a tool and technique used during the *plan quality and control quality processes* [52, pp. 285, 303]. This study not only provides inputs into the specifics connected with conducting different testing in the field of DWH projects but also provides guidelines on what components are tested and how they should be tested. These inputs can be used by project managers when planning different testing activities.

5) RESOURCE MANAGEMENT

Three studies from this literature review are mapped to the resource management PMKA and project initiation/planning DWH stage. Findings from the identified studies show that project managers play an important role in staffing and the recommendations from [S20] and [S23] should be applied when new teams are formed. When considering the staffing for the role of the project manager or project manager assistant findings from [S19] can be of interest since they are written from a project manager's perspective.

Rahman contributed to the DWH PM BOK with a review of lessons from a DWH implementation from a project manager's point of view [S19]. Rahman describes the innovations and techniques used and the benefits achieved in the context of team organization during a DWH project. Rahman describes how the project manager played a key role in selecting the team members most suitable for a project. Rahman emphasizes technical background, leadership, good relationship with top management, experience, and maturity as important skills of project managers in the context of team management. He points out that project managers with a business background can only be helpful from a business perspective and have to depend heavily on technical leads for all development tasks. Project managers with technical backgrounds can achieve better communication with the developers, assist team members in overcoming technical challenges, and make quick decisions when a technical challenge is encountered. The study also provides review of different practices and techniques the implementation team used to clearly define responsibilities between different roles. Findings from [S19] are of special interest to the PM community since they are written form a project managers perspective. This is the only such study identified in this literature review.

In the context of mapping with the PMKA, in the *PMBOK® Guide*, the role of project managers is mentioned through the resource management PMKA since project managers are responsible for team formation and achieving high team performance [52, pp. 309, 337]. The interpersonal skills of project managers, in the context of team management, which are described in this study, are outlined in the *develop team* process [52, p. 341]. Additionally, tools and techniques for communicating team member roles and responsibilities, which are also addressed in this study, are described as *data representation* techniques in the *plan resource management process* [52, p. 316].

In [S23], Shin provided a description of the staffing process during a DWH project. Shin presented the project organization that was used, including responsibilities within in it. The project organization was composed of the following five entities: the planning board, project board, project team, key stakeholders, and key resources. The planning board is the highest body in the organizational chart and is in charge of strategic alignment with business processes. The project board is responsible for the overall planning, coordination, and evaluation of the project. The project team's central function is to lead the project effort through the coordination and facilitation of activities, such as scope management, scheduling, setting goals, training sessions, and controlling the progress. The key resources entity comprises end users of the DWH and members who provide support in technical training and information repository. Finally, the key

stakeholders group consists of representatives from the departments that would be affected by the new DWH system. In the context of the mapping with the resource management PMKA, the proposed organizational chart can be seen as an example of industry-specific resources that are required for DWH projects [52, p. 311] and how the relationships between them are defined. Furthermore, this study can also be viewed as *expert judgment*, with recommendations on how to define the roles and responsibilities of the project team [52, p. 315]. These are defined in the *resource management plan* [52, p. 318].

Davis *et al.* conducted a study on the effects of joint IT competence and partnership between users from functional departments and information system (IS) departments on higher user satisfaction in IS implementations [S20]. User satisfaction with the IS implementation was measured by the level of involvement in the development, operation and use of the system and by the amount of support and service provided. The study results confirmed the hypothesized relationships among joint IT competence, partnership, and user satisfaction and showed that higher levels of joint IT competence lead to more equally shared decision-making between users and IS personnel during implementation. Based on the study's findings, Davis *et al.* also emphasize the value of having IT-competent users from the functional department included throughout complex IS projects. In a similar fashion, managers should also work on strengthening weak areas of IT competence within business users, either during the hiring process or through training programs. Project managers should hence ask for IT experienced business end users to join and take an active role in their DWH projects.

As stated in the *PMBOK® Guide*, project managers are also responsible for proactively developing team skills and competencies [52, p. 309]. The findings from this study can help tailor the *decision-making* technique, i.e., when choosing different selection criteria for team resources [52, p. 332]. As the findings from this study indicate, project managers should negotiate to acquire business users with IT competences for DWH projects. Finally, as advocated in the study, training team members to obtain IT skills is also covered in the *develop team process* [52, p. 342].

6) COMMUNICATION MANAGEMENT

Three studies are identified in the area of communication management during the project initiation/planning DWH stage. These three studies present a set of papers [S21], [S32], [S33], which are concentrated on the communication aspects of financial DWH projects. In general, even though these studies are based on case studies from bank DWH implementations it is noticeable they lack practical guidance and are more theory oriented. However, some directions for communication analysis are provided.

First, in [S33], Behrmann and Räkers analyzed three case studies of financial DWH projects and presented specifics and lessons learned. The findings suggest that specification-based communication between members is not sufficient and that more face-to-face type of relations is needed due to different interpretations of specification. This is caused by divergences in knowledge and experience that different team members have. Additionally, the authors state that financial DWH projects require knowledge transfer through personal communication among team members due to frequent fluctuation in teams. The authors conclude by saying that project managers should adapt their approaches in order to address the communication requirements of financial DWH projects.

In [S21], Räkers and Rosenkranz presented a communication efficiency model for financial DWH projects. The presented theoretical model is based on the rationale from a communication efficiency study [99] and tested against findings from [S33]. The findings suggest that when problems in communication occur and project management teams introduce a change in action, in order to solve the problem, this action results in the creation of a more shared and joint terminology. It is stated that this new terminology led to increases in efficiency and finally project success. In [S32], Räkers further enhances the model from [S21] by introducing additional factors, such as cost, performance, and complexity. The findings from this study also suggest that project managers should make decisions on switching to different *styles of communication* or terminology when faced with different levels of complexity in financial DWH projects. A limitation of [S21], [S32] is the lack of examples of the changes in terminology.

The *PMBOK® Guide* also recognizes differences in communication styles, which can come from diversity in professional background, culture, or working methods [52, p. 373]. It is these challenges on which the models in [S32], [S33] were based. The three studies described above can also be seen as *expert judgment* from individuals with experience in the specific industry (DWH), which is considered a tool and technique described in the *plan communication management process* [52, p. 369]. Finally, the findings from [S21], [S32], [S33] can be incorporated into the *method for updating and refining the communication management plan* as the project progresses [52, p. 377].

7) RISK MANAGEMENT

Two studies are identified in the area of risk management during the project initiation/planning DWH stage. Both of these studies show good examples of how risk management [S22] and specific risks [S23] are addressed in real world implementations.

Legodi and Barry addressed the risk management aspect of the enterprise DWH development projects in South Africa [S22]. The study findings indicate that risk management is adopted in DWH implementation, the project teams are familiar with the risk management approaches, and the teams find that risk identification an important segment of DWH projects. However, the extent to which risk management is performed requires some improvements because there is no formal process for risk response planning, monitoring, and controlling risk. The participants indicated that the most

common problems are schedule overruns, budget overruns, and poor-quality deliverables. The findings also indicate that risks to projects happen due to inadequate stakeholder management, poor analysis due to time constraints, and insufficient support from team members during risk identification. Experience is found to be the main factor for overcoming the previously stated implications.

Shin described how risk assessment was conducted in the preinitiation stage of a 6-month pilot project for DWH implementation in an insurance company [S23]. Shin stated that many DWH projects fail in the initiation stage and that therefore risk assessment and mitigation strategies should be defined in the early stages of the project. The study contains descriptions of several risks identified throughout the project and mentions technological, organizational and business cases risks as the ones with the highest impact. The conducted risk assessment also identified many identified risks in project management areas, such as project planning, change control, user expectations, and scope and communication management. The authors stressed the importance of identifying end users and key users of the DWH since their feedback is crucial for development.

Both [S22] and [S23] provided insight into potential sources of risk in DWH implementations. The *PMBOK® Guide* recognizes *academic studies* in the context of *expert judgment* as a factor that can influence the *identify risks process* [52, p. 413]. In addition, [S22] provides insight into how other processes from the risk management PMKA, such as *plan risk responses, implement risk responses,* and *monitor risks*, have not been properly defined. The findings from this study can also be considered as external *expert judgment* used during the *plan risk management process* [52, p. 404].

B. REQUIREMENT ANALYSIS

1) SCOPE MANAGEMENT

This literature review resulted in six studies that address the area of scope management in the requirements analysis stage. Studies identified in this area either propose a specific approach to gathering requirements [S12], [S26], [S27], [S28] or describe specific techniques and practices for gathering, defining, and prioritizing requirements [S24], [S25].

In the context of the scope management PMKA, the *PMBOK® Guide* advises that the expertise from individuals or groups, expertise from the industry, discipline, and the application area should be considered during the *plan scope management, collect requirements, and define scope processes* [52, pp. 136, 142, 153]. Therefore, the findings from all studies identified in this area can be viewed as *expert judgment* in the scope management PMKA. Additional mappings with the scope management PMKA are provided below.

In [S26], Winter and Strauch presented a methodology for determining DWH information requirements. In the center of this methodology is a 4-phase model for information requirement analysis. The study also contains graphic illustrations of the relations between the concepts of information demand, information supply and information provision. Furthermore, Winter and Strauch stressed that analyses of DWH information requirements should be based not only on information demand but also on the current and future supply of information. In their later study [S27], Winter and Strauch explained how they developed the activity model for the methodology proposed in [S26]. Interestingly, the model was developed based upon interviews conducted with DWH project managers. Derived from these inputs, Winter and Strauch formed a list of eight requirements, which improve the effectiveness of the information requirement analysis phase. Later, the authors confirmed the importance of the suggested requirements list by analyzing four case studies of large organizational DWH projects. The proposed model for DWH requirements analysis methodology should be analyzed when developing the *requirements management plan* during the *plan scope management process* [52, p. 137].

Salinesi and Gam investigated and compared traditional operational systems and decision information systems from the perspectives of users, data, usage, database structure, and system administration [S28]. In their paper, the authors concluded that there are differences in the perspectives stated above, which indicates that DWH systems require a tailored approach for requirements analysis. Salinesi and Gam highlight the neglect of requirements that relate to the company's business strategy. Keeping this issue in mind, the authors propose a method for requirement analysis named Computer-aided data warehouse engineering), which defines four types of requirements that need to be incorporated into the requirements model. Salinesi and Gam point out that project managers need to pay attention that requirements are not overlooked in the communication between the implementation team and DWH users.

Many DWH approaches use business processes as metrics in project planning [7], [100], [101]. Aljawarneh [S12] proposed a framework for requirement specifications. In her framework, one of the outputs of the first *interview stage* is to categorize relevant business process groups into different groups based on their source supportability and business values. A similar method was suggested by Kimball [7, p. 33] that prioritizes business processes based on their importance and feasibility. This method is useful during planning since it recommends that business processes that are of the most importance for the company and have the highest feasibility and that source support be analyzed and implemented first. These projects can be categorized as business-driven rather than data-driven. Other studies identified in this literature review also advocate that DWH projects should be business-driven [S2], [S3].

In the context of scope management, the *PMBOK® Guide* states that "*the project manager is responsible for ensuring that requirements-related work is accounted for in the project management plan and that requirements-related activities are performed on time and within budget and deliver value*" [52, p. 132]. The approaches to requirements analysis and

findings presented in [S12], [S26], [S27], [S28] should be considered by project managers when developing the *requirements management plan* for their projects [52, p. 137].

In [S24], Bunio describes a number of agile DWH practices that were used in a project of which he was a part. In the context of defining the project scope, during the requirements gathering stages, Bunio describes the used agile practices surrounding the creation and sharing of the *enterprise data models*, where data requirements are iteratively reviewed by the team as the project progresses. It should be noted that from all of the studies discovered in this literature review, [S24] had the most practical advice and lessons learned listed.

Prakash and Prakash [S25] proposed a model for user story creation in agile DWH environments called the *Decision Application Model* (DAM). In this model, user stories are customized to the DWH environment such that they express *"information required by a stakeholder for taking a decision"*. The DAM approach describes how DWH requirements are defined on three levels: application, decision, and information. In this approach, the use case backlog is created from decision and information requirements for a single application requirement.

The techniques and findings presented in [S24], [S25] can be used by project managers when considering different data gathering, data analysis, decision making, and data representation techniques during the *collect requirements process* [52, pp. 142–144]. Likewise, the described techniques can be considered as product analysis techniques, which are used in the *define scope process* [52, p. 153].

2) COMMUNICATION MANAGEMENT

The literature review resulted in 2 articles that describe aspects of communication management PMKA during the project requirements analysis DWH stage [S24], [S29]. These studies show examples of how to integrate communication into requirement analysis. Findings from [S24] are more beneficial to project managers since they are more practically oriented.

Rosenkranz *et al.* highlighted the problem of *semantic heterogeneity* in DWH development [102] and proposed a development approach for data integration based on communication theory and agile software development [S29]. The authors highlight three main principles of communication (communication is a joint activity, communication depends on a grounding process, and communication is a multimodal process) and present their implications and consequences for DWH data integration development. The presented development approach consists of three artifacts: a template for specifying business information and data integration requirements (e.g., schema mappings), a procedure based on agile practices, and a custom-made software tool. The findings suggest that semantic heterogeneity can be overcome via intensive communication and the development of common ground between stakeholders. In the context of mapping with the communication management PMKA, the results from this study can be viewed as *expert judgment*, which is considered during the *plan communication management process* [52, p. 369]. Finally, the findings from this study can be beneficial when conducting the *communication requirement analysis* and taking into consideration the specifics behind DWH development [52, p. 369].

Bunio described how using large posters of *enterprise data models* inside a collocated team room improved data requirements and model design specifications [S24]. This practice was reported to have benefited the communication since all members were motivated to draw their data requirements and openly discuss them with other team members. According to the *PMBOK® Guide,* collocation, or the physical location of team members, should be considered when tailoring the communication management processes [52, p. 365]. The described use of *the enterprise data model* is an example of how different media can be used to disseminate information and how facilitation can be applied to overcome stakeholders' communication obstacles. These are all considered techniques for effective communication management [52, p. 381].

C. DATABASE DESIGN

1) INTEGRATION MANAGEMENT

The literature search resulted in two articles [S30, S31], which are mapped to the integration management PMKA and are placed in the context of the database design DWH stage. These studies are more technically oriented than the others in this literature review, however since DWH project managers need to have good technical understanding, findings from these studies are also of relevance to the PM community. Database design method can have a significant influence on the overall project approach. Project managers should carefully consider the development approach. The studies below provide some insight into this manner, however, not much detail is provided in the discovered studies.

In the studies by Nemec [S30] and Rönnbäck [S31], the focus was more on database modeling and hence development rather than PM practices. However, the authors state that these approaches effectively compliment the agile method of DWH development and can contribute more to the flexibility and scalability of the DWH and hence to the success of the DWH implementation. Comparison of different development approaches are an important conversation topic between the solution architect and the project manager.

Nemec analyzed how well different database modeling techniques complement an agile BI solution [S30]. The author compares normalized DWH, dimensional DWH, data vault modeling [103], and anchor data modeling [S31], which are the most widely used approaches. Nemec then measures how these four approaches contribute to (1) the flexibility and change treatment of the DWH and (2) optimization for querying large amounts of data. The results of Nemec's study indicate that Kimbal's dimensional modeling DWH approach handles flexibility and change treatment the best, whereas

data vault and anchoring techniques perform best for querying large amounts of data.

In a study by Ronnabeck *et al.,* the anchor modeling approach is described and proposed in more technical detail [S31]. The authors describe several benefits of anchor modeling techniques, such as the ease of modeling, simplified database maintenance, and high performance. Interestingly, the authors state that the anchor modeling approach facilitates iterative and agile development since it allows work to be performed on small subsets of the model.

Similar to studies identified in the project initiation/planning DWH stage and integration management PMKA, the findings from the two studies described above can be assessed during the process of tailoring the project integration management process. More specifically, these inputs may be beneficial while developing the development life cycle [52, p. 74]. Moreover, these inputs can be viewed as an *enterprise environmental factor*, i.e., a PM BOK from specific industries that should be incorporated into the PM plan [52, p. 84]. Finally, the chosen approach to design the database should be integrated into the overall development approach and hence documented as a component of the project management plan [52, p. 88].

D. ETL DESIGN

1) SCHEDULE MANAGEMENT

The literature review resulted in a single article that describe aspects of the schedule management PMKA during the ETL design DWH stage. It is surprising to see that only one study covers this topic since it is reported that the ETL process is one of the most difficult and time-demanding stages in a DWH project. Studies indicate that between 50% and 80% of effort on information projects is spent on some sort of ETL task [5], [31], [50], [98] and [S15].

With the goal to better plan and estimate the ETL part of the DWH project, Rasool & Malik developed an effort estimation model [S11] using forward stepwise regression (FSR). The model is based on a set of predefined prediction variables: the number of different types of sources for data extraction, the number of tables used for sorting data, prior experience in developing similar ETL projects, the degree of documentation and suitability of source data for target systems, and the number of hierarchies representing the level of details in data. Rasool & Malik gathered data from 220 projects from five software companies and used FSR to build a prediction model investigating the relationship between the independent variables stated above and a dependent variable: the number of hours required for the ETL task. The model proposed in this study was found to be more precise at estimating than the more generalized COCOMO II model [104]. In the context of the schedule management PMKA, the findings from this study can be viewed as *expert judgment*, and the proposed model can be used as a technique for estimating during the *estimate activity durations process* [52, p. 195].

E. QUERY/REPORTING DEVELOPMENT

1) SCOPE MANAGEMENT

The literature search resulted in 1 article, which is connected to the area of scope management in the query/reporting development DWH stage [S24]. As stated before, this study contains the most practical guidance from all of the studies that resulted in this review.

In [S24], Bunio describes how a technique, a customized version of the *Prune the Product Tree* game [105], [106], was implemented on a DWH project in order to define and prioritize user reports [S24]. In his project, this technique was used to gather information about the top 15 report requirements for specific business areas, identify the most important and frequent reports, and educate business users on the differences between system and self-service reports. The results were then incorporated into a report backlog, after which specific user stories were created. The user stories were then mapped to the *enterprise data model* in order to show the areas and data required. Finally, the user stories were put in a backlog and implemented through iterations. The following technique can be considered by project managers as a requirement prioritization technique, which should be addressed in the *requirements management plan* [52, p. 137]. This technique can also be viewed as a joint application design/development technique [52, p. 145] in which the project team analyzes, gathers and defines requirements in a cooperative fashion. Finally, since the technique is also used as a way to define what reports will be in the scope of the project, it can also be considered a *product analysis* technique, which should be used to define product scope [52, p. 153].

F. PRODUCTION USAGE AND MAINTENANCE

1) STAKEHOLDER MANAGEMENT

The literature search resulted in a single article, which has references to the stakeholder PMKA in the production usage and maintenance DWH stage. This is also a striking discovery since DWH projects are reported as never-ending [49], [82] and [S23].

In [S1], Ramamurthy *et al.* mentioned the need for continuous stakeholder engagement not only throughout the project but also after the project is in production in order to ensure organization-wide buy-in from key DWH users. Stakeholders should be managed in order to promote and motivate users to use the DWH and to help in resolving potential change request conflicts and information disputes. In the context of mapping with the stakeholder management PMKA, the suggestions from this study can be viewed as *expert judgment* during the *plan stakeholder engagement process* [52, p. 520].

V. DISCUSSION

In this section the answers to the research questions are provided in subsections A to F.

A. WHAT METHODOLOGIES, PRACTICES, TOOLS AND TECHNIQUES, CAPABILITIES PROFILES, AND DEVELOPMENT PRACTICES ARE COVERED IN THE DISCOVERED LITERATURE? (PRQ1)

The discovered methodologies, practices, tools and techniques, capabilities profiles, and development practices are presented in Table 4.

Based on the findings from Table 4, Figure 3 above displays the number of identified PM-related content categorized by inclusion criteria. Figure 3 shows that inclusion criterion 3, capability profiles, is the most present type of PM-related content in the discovered literature, followed by inclusion criterion 1, methods and processes. Inclusion criterion 4, development practices is the least discovered criterion, which is expected due to the specific search strings used. Again, it should be noted that a single study can satisfy multiple inclusion criteria.

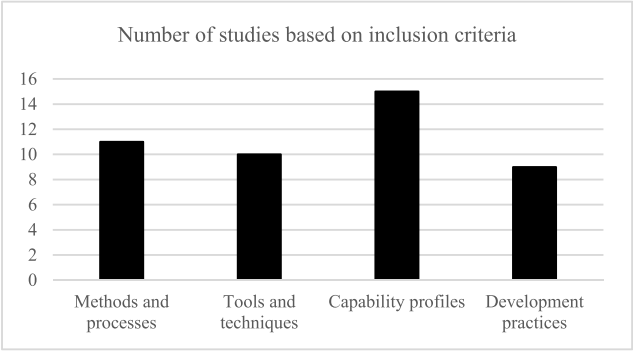

FIGURE 3. Literature results per inclusion criterion.

If we look closely at the discovered PM-related categories the following conclusions and remarks are made:

- Studies marked under global considerations [S1, S3, S7, S13, S23] have useful considerations and focus points for successful implementations. Project managers should consider the findings from these studies when starting the project.
- Most of the discovered methods and processes are of low usability to practitioners since they are not described or elaborated in sufficient detail in their original studies. This is especially true if we take into considerations that based on the PMI and PRINCE2 standards, project managers are used to having elaborate descriptions of methods and processes. The ones discovered in the studies resulting from this literature review are mostly just diagrams or illustrations with main process activities and steps and with very brief instructions.
- Only two methodologies that can be considered as PMM are discovered ([S2, S8]). Even so, these are not elaborated in sufficient details, as only high-level overviews are provided.
- Only a small number of studies examined PM as a variable and its effects on project success in DWH projects. Studies [S1], and [S3] discovered PM as a variable that has an influence on project success. In S5 it was discovered that PM should be used alongside agile practices in order to achieve business value in DWH.
- Only one study was written directly from the project managers perspective ([S19]).
- Metadata management was discovered as an important practice in DWH projects.
- Several authors agree that DWH should be built with the goal to achieve flexibility and scalability ([S2, S3, S6, S7, S27]).
- Very few studies mention the structure of the involved project team and explain how the communication between the team members was organized. Most of the studies mention end users and IT department as key roles however these are not elaborated in more detail.
- In the selected studies, agile practices are covered heterogeneously. Studies by Batra analyze the factors that affect the application of agile in DWH [S5] and later evaluate its effects on achieving project succes [S4]. [S6] provides practices for change management that are in line with the agile framework, however without sufficient detail. Two studies propose specific models for certain techniques; [S10] for sprint planning and [S25] for user story creation. Bunio ([S24]) describes the agile practices used in a case study project and Goede ([S9]) evaluates the application of current agile frameworks in student DWH projects. Stronger conclusions or similarities concerning agile were not discovered in the analyzed set of studies.
- Even though it is reported that DWH project breach planned budgets ([S13, S15, S22] and [30]–[32]) only two studies focus on the cost aspect ([S14, S15]) of DWH projects.

B. HOW ARE FINDINGS FROM THE DISCOVERED LITERATURE MAPPED TO THE PÌ KNOWLEDGE AREAS (PMKAS) FROM THE PMBOK®GUIDE AND TO THE DWH STAGES? (PRQ2)

Table 6 summarizes what is elaborated on in Section IV and shows the studies in the context of the two research dimensions. In Table 7 findings are quantified based on the number of studies in each area. Table 8 represents a heat map type of report based on the finding that some of the studies from this literature review also provided content regarding more than one PMKA and DWH stage. However, the discovered content in these studies was not elaborated in much detail or focused enough to be included in the results presented in Tables 6 and 7, i.e., in the Findings section. However, a heat map type of report was created with a goal to provide an additional perspective on how studies and hence, the discovered PM-related content is distributed among the two dimensions. The report is based on the following rules. Every study from Table 6 is given 1 point based on its primary focus. For example, in Table 6, for the project initiation/planning DWH stage and risk management PMKA, two studies are identified. Therefore, 2 points were added to the field, which represents

TABLE 6. Review of findings compared to two dimensions.

	Integration	Scope	Schedule	Cost	Quality	Resource	Communication	Risk	Procurement	Stakeholder
Project initiation/planning	Ramamurthy [S1]; Gardner [S2]; Sammon & Finnegan [S3]; Batra [S4], [S5]; Li [S6]; Wixom & Watson [S7]; Golfarelli, *et al.* [S8]; Goede [S9]; Solomon [S13]; Shin [S23].	(x)	Golfarelli, *et al.* [S10]; Solomon [S13].	Pratama & Rasywir [S14]; Gowan, *et al.* [S15].	Foshay, *et al.* [S16]; Watson & Haley [S17]; Golfarelli & Rizzi [S18].	Rahman [S19]; Davis, *et al.* [S20]; Shin [S23].	Marc & Rosenkranz [S21]; Räkers [S32]; Behrmann & Räkers [S33].	Legodi & Barry [S22]; Shin [S23].	(x)	(x)
Requirement analysis	(x)	Bunio [S24]; Prakash & Prakash [S25]; Winter & Strauch [S26], [S27]; Aljawarneh [S12]; Salinesi & Gam [S28].	(x)	(x)	(x)	(x)	Bunio [S24]; Rosenkranz, *et al.* [S29].	(x)	(x)	(x)
Database design	Nemec [S30]; Ronnback, *et al.* [S31].	(x)	(x)	(x)	(x)	(x)	(x)	(x)	(x)	(x)
ETL design	(x)	(x)	Rasool & Malik [S11]	(x)	(x)	(x)	(x)	(x)	(x)	(x)
Query/reporting design	(x)	Bunio [S24].	(x)	(x)	(x)	(x)	(x)	(x)	(x)	(x)
Production usage and maintenance	(x)	(x)	(x)	(x)	(x)	(x)	(x)	(x)	(x)	Ramamurthy [S1].

TABLE 7. Number of findings based on the two research dimensions.

		Dimension one: Project management knowledge area											
		Integration	**Scope**	**Schedule**	**Cost**	**Quality**	**Resource**	**Communication**	**Risk**	**Procurement**	**Stakeholder**		
Dimension two: DWH stage	**Project initiation/planning**	11	0	2	2	3	3	3	2	0	0	**26**	**Sum**
	Requirement analysis	0	6	0	0	0	0	2	0	0	0	**8**	
	Database design	2	0	0	0	0	0	0	0	0	0	**2**	
	ETL design	0	0	1	0	0	0	0	0	0	0	**1**	
	Query/reporting design	0	1	0	0	0	0	0	0	0	0	**1**	
	Production usage and maintenance	0	0	0	0	0	0	0	0	0	1	**1**	
		13	**7**	**3**	**2**	**3**	**3**	**5**	**2**	**0**	**1**		
		Sum											

the area stated above. Later, for every study that provided additional content, 0.25 points were given if it provided content in a smaller amount, or 0.1 points if it provided content in the minimal amount, based on the qualitative analysis. Finally, the areas with the highest reported content are presented in red, whereas the areas with the lowest are presented in green. Table 10 in Appendix B provides the additional content discovered and the number of points awarded for each study.

Moreover, some of the findings from the identified studies recount different stakeholders in DWH projects. However, it should be noted that these studies do not describe or concentrate on how to identify, plan, manage or control these stakeholders but rather only recognize them. In Table 11 in Appendix B, a list of identified stakeholders and the context in which they are presented or analyzed in the literature review is provided. In the context of the mapping with the stakeholder management PMKA, these studies can be viewed as *expert judgment,* used in the context of *identify stakeholder* and *plan stakeholder engagement processes* [52, pp. 511, 520]. For each study listed in Table 11, 0.1 points are added to stakeholder management PMKA in the project initiation/planning DWH stage in Table 8.

In the context of the two dimensions, the project initiation/planning DHW stage and integration management PMKA are mostly covered in the literature. The majority of

TABLE 8. Review of findings presented as a heat map.

		Dimension one: Project management knowledge area											
		Integration	Scope	Schedule	Cost	Quality	Resource	Communication	Risk	Procurement	Stakeholder		
Dimension two: DWH stage	Project initiation/planning	11.1	0	2.35	2	3.2	3.1	3	2.1	0	1.2	28.05	Sum
	Requirement analysis	0.1	6.3	0	0	0	0	2	0	0	0	8.4	
	Database design	2.1	0	0	0	0.1	0	0	0	0	0	2.2	
	ETL design	0	0	1	0	0.2	0	0	0	0	0	1.2	
	Query/reporting design	0	1	0	0	0.1	0	0	0	0	0	1.1	
	Production usage and maintenance	0.2	0	0	0	0.1	0	0	0	0	1	1.3	
		13.5	7.3	3.35	2	3.7	3.1	5	2.1	0	2.2		
		Sum											

the studies that fall into this area present global considerations for DWH projects or present guidelines on how better to organize or manage the DWH project. Studies in the area of requirement analysis DWH stage and scope management PMKA were the second-most-covered topic. In this area, most of the papers focused on different approaches to gathering and analyzing user requirements.

The biggest gap was discovered for the procurement management PMKA, for which no studies were identified, regardless of the DWH stage. Additional search for terms such as ''contracting'' or ''procurement'' did not result in studies that address the procurement part of DWH implementations. Therefore, it is evident that this area needs additional research.

When the summed values from Table 8 are compared with the values from Table 7, it can be noted that, in the context of the two research dimensions, the biggest increase was identified in the stakeholder management and quality management PMKAs, followed by the integration management PMKA. On the other hand, the biggest increase in findings was found in the project initiation/planning and requirements analysis DWH stages. To the contrary, no additional findings were discovered for the communication management PMKA. Similarly, the smallest number of additional findings was detected in the query/reporting DWH stage. It should be noted that again, no results could be attributed to the procurement management PMKA in the heat-map report. In the context of the two research dimensions, the procurement management PMKA remains the PMKA with the biggest identified research gap.

C. DOES THE DISCOVERED LITERATURE ADDRESS THE MOST COMMON RISKS AND CHALLENGES IN DWH IMPLEMENTATIONS? (SRQ1)

In the following text, we identify some of the most common risks and challenges and see whether the studies from this literature review provide appropriate guidance.

Several studies mention the risk of applying an untailored methodology, such as [S23] *and* [6]. Studies discovered in this literature review that classify global considerations for DWH projects [S1], [S3], [S7], [S13], [S23] can be a good starting point when defining a methodology. Furthermore, findings from [S2], [S8] directly provide examples of methodologies used in DWH projects. In addition, the authors of several identified studies advocate that the DWH should be incrementally built and that flexibility and scalability are some of the most important development goals [S2], [S3], [S6], [S7], [S27]. These findings can help guide the development approach. Studies from this literature review identified in the resource management and communication management PMKA and project initiation/planning DWH stage [S19], [S20], [S21], [S23], [S32], [S33] can also be purposeful when defining the project organizational structure and communication methodology elements.

DWH projects require high levels of control and progress tracking [5]. Gowan *et al.* described how the traditionally used EVM technique should be tailored for DWH projects [S15]. Additionally, the identified studies that address agile principles and techniques in DWH projects can help with this challenge, such as [S4], [S5], [S6], [S9], [S10], [S24], [S25].

Scope creep [5], *in addition to long implementation durations* [29], *requires adequate scope management in DWH projects.* The findings under the requirement analysis PMKA in this study provide some examples for scope management. In addition, studies identified in the scope, schedule, cost, and quality PMKAs can help with handling the traditionally defined *iron triangle* [107]. The study by Wixom and Watson [S7] and [S1], [S13] can also provide a wider perspective when setting additional critical success factors in DWH projects.

It is not a rare occurrence in DWH projects that users of the old system feel that their position will become obsolete when the new DWH system is implemented and hence refuse to share important information [5], [50], *during the requirements analysis and model definition stages.* Several studies identified in this review address this issue. For example, in [S24], Bunio describes techniques that unify the project team and provide a common ground for joint collaboration. In [S1], Ramamurthy explains how specific stakeholders can help with information disputes.

Another common impediment found in the literature is dirty data [5], [50]. The studies by Foshay *et al.* [S16] and Watson and Haley [S17] focus on metadata, its importance in DWH projects, and its connection with positive user attitude towards implemented DWH systems. Additionally, Golfarelli and Rizzi researched data quality testing activities [S18]. In addition, several other studies identified in this literature review also address metadata and testing aspects, as can be observed in Appendix B.

Even though every DWH implementation caries unique impediments and risks, it can be stated that the studies identified in this literature review address some of the most common challenges and can therefore be used as guidelines by DWH project managers and practitioners when defining risk mitigation tasks.

D. TO WHAT EXTENT ARE PROJECT MANAGERS PRESENTED AS THE PRIMARY READERSHIP OF THE DISCOVERED LITERATURE? (SRQ2)

Based on the data from Table 5 it can be noted that 11 of the identified 33 studies (33.3%) specifically addressed project managers as one of the targeted readerships of the study. Even though 33.3% may not seem like a small percentage, it is my opinion that 11 studies is a too small number for such a field with such high numbers of underachieved results and project failures. This is an even bigger problem when looked from the perspective that the majority of the main electronic sources of primary literature have been covered in this review (including the most influential journals for the PM community – PM Journal and International journal of project management) and that search terms used were quite broad in their coverage. Even though PM-related content has been discovered in all of the identified studies it is assumed that the narrative and guidance from studies that are directly aimed at the PM community are of most relevance to them.

E. TO WHAT EXTENT DOES THE CURRENT LITERATURE PROVIDE EMPIRICAL EVIDENCE? (SRQ3)

Based on the data from Table 5 only 10 studies (30%) displayed empirical evidence in their research. This is an indicator that in the present-day literature there is not enough empirically backed up studies. This may cause a problem for project managers and practitioners who may then question the applicability of suggestions proposed in the literature. Researchers in this field should be motivated to provide more empirical evidence in their studies in order to demonstrate more solid recommendations to the practitioner community.

F. WHAT IS THE STRUCTURE OF THE IDENTIFIED LITERATURE (PUBLICATION TYPE (JOURNAL ARTICLE OR CONFERENCE PROCEEDINGS), CLASSIFICATION OF THE LITERATURE BY PAPER TYPE, AND THE AGE OF THE LITERATURE)? (SRQ4)

To better understand the context of the literature search results, a number of statistical reports are created. Figure 4 inspects the literature search results based on their type. Since

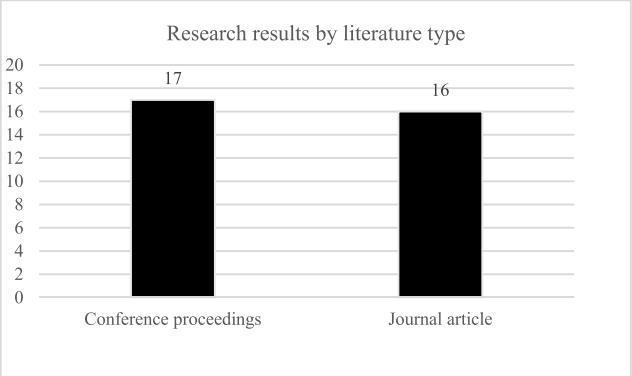

FIGURE 4. Literature results per literature type.

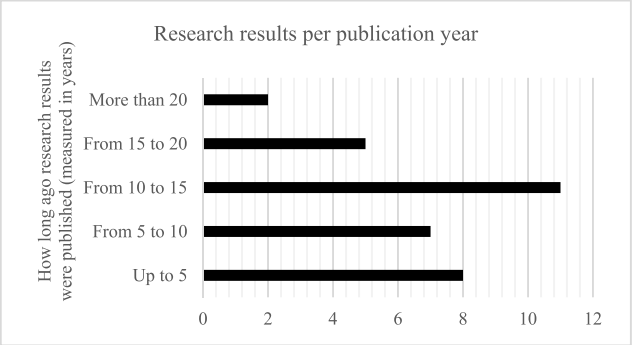

FIGURE 5. Literature results per publication year and type.

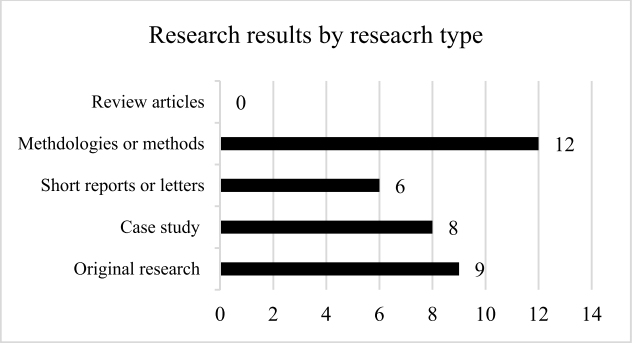

FIGURE 6. Number of research results by research classification.

book chapters were out of scope of the literature review, studies were either conference proceedings or journal articles. This literature review has an almost even distribution between the two types, with a slightly greater number of conference proceedings than of journal articles. Next, the resulting literature was analyzed in terms of the publication date in order to check the age of the discovered literature.

From Figure 5, it can be seen that the greatest number of papers reviewed in this study are between 10 and 15 years old. Even though it would be better to have more recent studies on the topic due to the evolving nature of the DWH field, out of the 8 studies published in the period from 2015 to 2020, 6 studies were published in the last three years.

TABLE 9. Agenda for future research.

Identified research gap or finding	Future research agenda/question
There is not enough research in DWH that is focused on project managers.	Only 11 studies (33.3%) were discovered in the literature review that were aimed at the project manager role. Furthermore, only 1 study was written from the project managers perspective [S19] and only two studies are discovered to have been conducted based on interviews authors had with DWH project managers [S23, S26]. It is evident from these numbers that the project manager role has not been addresses appropriately in the current BOK on PM in DWH. More studies motivated by project manager's problems, best practices and knowledge should be done in order to enrich the current literature.
Research gap identified for the procurement management PMKA.	The findings from this study do not explain why the procurement management PMKA resulted in no findings in this literature review. This phenomenon should be additionally investigated by researchers. Procurement management might have an important role in DWH projects and may be a factor in the large number of reportedly failed DWH projects. Project managers may want to allocate extra effort when negotiating the terms of the DWH implementation and defining the related contract because the success of the implementation will, to a significant degree, be assessed based on the scope and time obligations defined in the customer-supplier contract. In addition, it would be very beneficial to the practitioner community to examine whether some form of agile contract that promotes iterative and incremental delivery and planning [113] could be used to redefine obligations in the regards of timeline, scope, and budget on DWH projects. However, as shown in this review, the current literature does not provide further details with respect to this challenge. Additional research is required in order to provide an answer as to whether the identified gap is justified. On the other hand, it should be stated that books about DWH implementations [5], [31], [80], provide significantly more content about the procurement management aspect. These books provide descriptions of techniques and aspects that are a very important part of the contractual agreement, such as user responsibilities, availability requirements, access tools, team roles and responsibilities, out-of-scope features, change management, assumptions, risks, service-level agreements, etc.
Identified research gaps in Table 6.	Table 6 clearly identifies fields that require future research. Based on the results, only two areas (Project initiation/planning DWH stage and integration management PMKA and Requirement analysis DWH stage and scope management PMKA) have adequate research. Other areas need additional research since they are very poorly covered in the current literature. These findings allow researchers to focus their research in to identified areas with gaps. For example, even though the ETL stage and ETL-related activities are estimated to encompass anywhere from 50% to 80% of time on IS projects [5], [31], [50], [99], this literature review resulted in only one study on this topic. This is a clear gap that should be addressed in future research. Poor research results are also evident for the query/reporting design and production usage and maintenance DWH stages. Only one study regarding these DWH stages was discovered. These stages are also very important segments of the DWH implementation since users usually exploit benefits from the DWH systems by extracting data via custom queries or reports and do so once the system is in the production stage. Furthermore, several studies from this literature review mention that DWH implementations are never-ending and are constantly enhanced and upgraded [49], [82] and [S23]. The low number of research results in these DWH stages might again be attributed to inadequate search terms. The term business intelligence is more related to this context than DWH. However, business intelligence was not in the scope of this study.

TABLE 9. *(Continued.)* **Agenda for future research.**

	Cost management of DWHs is also an important topic that has not been researched adequately. Some of the important questions for future research in the cost domain are: what are the hidden costs in DWH projects, how to decrees the overall budget needed, what are the benefits of using open source software instead of traditional high cost software for Database, how is scalability and size of DWH connected to its costs, techniques to monitor and track costs, etc.
How to achieve DWH flexibility and scalability.	Flexibility and scalability of DWH is mentioned in several studies as one of the main goals when implementing a DWH [S2, S3, S6, S7, S27]. It is clear from the results that applying the right development approach plays a crucial role in achieving these goals and several techniques are evaluated, f.e. in [S30]. However, the discovered studies do not provide practical advices on how to achieve this and what techniques should be used. A comparative analysis of several most used development approaches may be beneficial to project managers. In addition, research on the topic of DWH flexibility and scalability success factors may also be of interest.
PMM are not elaborated in detail that would be sufficient for the project manager role.	Only two PMM are identified from the selected studies [S2, S8]. However, these are not elaborated in enough details for them to be used. No study elaborated on how currently available methodologies can be tailored in DWH projects. Only one study focused on this but its application is limited since it is based on findings from a student environment [S9]. More research with the focus on how to shape the PMM on DWH project would be beneficial to the PM community.
There is not enough empirical studies.	Only 30% of studies showed empirical evidence. Researchers should provide more empirical evidence in their findings in future studies.
There are no Post-mortem analysis and elaborations for failed DWH projects.	High failure rates in DWH projects are often cited as the primary motivators in identified papers [S13, S15, S22, S28, S30]. Post-mortem analysis of failed DWH initiatives would be of great value to the practitioner community in order to better understand the actions and the context that leads to DWH failure.
There is not enough focused research on the application of agile practices and frameworks in DWH projects.	From the discovered set of studies, it is clear that agile practices and frameworks can be used and that they can contribute to achieving success in DWH projects. However, all of the discovered studies seem to cover different topics in regards to the application of agile. More focused research on *how* to implement agile practices within currently available frameworks, such as *Scrum* in DWH projects is required. Case study and short report studies of successful application of agile practices will also contribute to wider application since such studies will elaborate more on this topic.
Few studies mention the structure of the project team and explain how the communication between the team members was organized.	The majority of the studies focuses on business users and members from the IT department as key users. Project champions and sponsors are also mentioned. However, the literature does not cover in enough detail the different roles that are needed inside the IT department and in business departments, such as testers, database admins, analysts, etc.
Categorization of findings from studies marked as "global considerations"	A set of studies that has been marked under global considerations [S1, S3, S7, S13, S23] has been found to contain useful advice for project managers. The findings from these studies have a lot of similarity, yet different terms and perspectives have been used by authors. A mapping study of discovered findings should be done in order to systematize and make the findings from these papers easily understandable to practitioners.

Next, we can analyze the resulting studies based on their research classification. For this purpose, the classification of research papers proposed by Springer [108] is used. The review of the studies is presented in Figure 6. Some studies satisfied multiple criteria. For example, some studies defined a research approach, which would classify them into the original research category, but also proposed a methodology or method based on the findings and were hence categorized into the methodologies or methods type.

The findings indicate that methodologies or methods is the most represented paper classification, followed by short original research, reports and letters, and finally case studies. From Figure 6, it can be seen that about one-third of the studies can be classified as original research. This, however, does not decrease the value of studies under different classifications since these are also valuable to the DWH practitioner community. In addition, this literature review did not result in any studies that could be classified as review articles. This finding is in line with the statement that no previous

systematic reviews of the PM field in the context of DWH have been conducted.

VI. LIMITATIONS

Specific actions were taken in order to address some of the most common threats to the validity of systematic literature reviews [109]. In the context of construct validity and internal validity, the following threats were addressed.

The threat of having conducted an inappropriate literature search was minimized by first finding the most relevant journals in the fields of PM and DWH, identifying their publishers, and then confirming that all publishers (except one) were included in the chosen online databases. More details about how the literature search was conducted are presented in Section III.

The threat of having inappropriate or incomplete search terms was mitigated since the search queries used included high-level terms such as *data warehouse*, *project management*, and *agile*. Several search queries that used more-specific terms, such as PMKAs or DWH stages, were also considered and tested throughout the process of developing the final query. However, these queries provided little to no search results. The logic behind using such general terms was based on the premise that studies had to, at a minimum, contain the specific terms mentioned above if they were to address the topic of this literature review. This premise was then tested and validated by conducting additional searches through gray literature and on Google Scholar.

Bias in study selection was managed by staying focused on the inclusion and exclusion criteria and improving them throughout the review.

Bias in the data extraction was treated by starting the literature process by first developing the problem formulation and the goal of the study. The inclusion and exclusion criteria, search queries, and online databases were chosen in alignment with the problem formulation and the goal of the literature review.

Author's bias: This systematic literature review has been conducted and prepared by a single author, which poses the question of the review's objectivity. As a mitigation action, journal reviewers and colleagues from the field of PM and DWH have been consulted for their comments and inputs on the review process and the presentation of paper's findings.

One of the limitations of this study was the exclusion of the literature in the form of books and book chapters. These were excluded due to the size and scope they covered. However, as noted in Section 3, these works are highly cited throughout this study. The conclusions of this study are nevertheless in line with the content of these books.

Additionally, it should be noted that some of the findings from the field of software development (or large-scale software development) PM may also apply to the field of DWH PM. However, since the field of software development PM is much broader and has more literature than the field of DWH project management, as indicated in Section II, this topic was not included in the scope of this study and hence should be analyzed in a separate paper.

It is worth mentioning that two papers [110], [111] could not be bought or accessed in any available way online at the time of the writing and hence fall under exclusion criterion four. These two papers satisfied the inclusion criteria and could have provided additional content to this study. However, since only abstracts could be reviewed, there was not enough information to further analyze these studies.

VII. PROPOSED AGENDA FOR FUTURE RESEARCH

Based on some of the findings from this literature review, answers to the research questions, and identified research gaps, in Table 9 we propose an agenda for future research.

VIII. CONCLUSION

Out of the 1145 initial search results, this literature review resulted in 33 studies in which PM-related content in the context of the DWH implementations was discovered. These studies were analyzed and interpreted in the context of the two research dimensions: the PMKAs from the *PMBOK® Guide* and the DWH stage. The following conclusions and implications were identified.

A. IMPLICATIONS FOR PROJECT MANAGERS AND DWH PRACTITIONERS

A reference map of identified studies and findings in the context of the PMBOK® Guide's PMKAs and DWH stage is created.

The findings from the literature review should be interpreted as a reference map on the subject of DWH PM. By looking at the results presented in Table 6, DWH project managers and practitioners are provided with reference points to discovered studies based on the area to which they apply. Findings from identified studies can then be consulted by project managers and DWH practitioners throughout their projects, since they are categorized into DWH stages.

Findings from studies marked under global considerations should be considered before starting a DWH project.

Studies marked as *global considerations* [S1, S3, S7, S13, S23] should be considered by project managers, in particular during the project initiation stage, since they provide high level guidance on how to approach a DWH project.

The current literature can be a good starting point for guidance on how to address most common DWH risks and challenges.

This review can also be a good reference point when planning for risk mitigation activities since the findings cover some of the most common DWH implementation challenges and risks (as elaborated in Section V, subsection C).

Project managers should address metadata management in DWH projects.

Metadata management was mentioned in several studies identified in this review. It has been shown that metadata plays an important role with respect to end-user acceptance

of the implemented DWH system since it helps them better understand the nature and quality of the data they are receiving from the DWH. Project managers should be extra wary since, as mentioned in one of the studies [S16], DWH practitioners are persistently aware that the quality of the metadata documentation delivered to the end-users is not to their liking.

The identified research gaps should be interpreted as a warning signal.

The research gaps discovered in the majority of areas in Table 6 should be interpreted as a warning signal for both DWH project managers and practitioners. More focused research is required in order to know more about PM in DWH. Even though there are successful DWH implementations, it is evident from this research that not a lot of written knowledge has been accumulated and reported in the primary literature over the years. It is argued that the current literature is *not sufficient* and hence project managers cannot rely on it for answers and guidance throughout the entire DWH lifecycle. Again, this study was aimed at assessing the current literature and its findings are an important first step in reducing these gaps and enhancing understanding of PM in DWH.

Discovered primary literature should be considered alongside books regarding PM in DWH.

Due to the large number of identified gaps in the current literature on PM in DWH, project managers and DWH practitioners should consider books, such as [5], [31], [81], as supplement literature when reviewing the primary literature.

B. IMPLICATIONS FOR RESEARCHERS

The current BOK in PM in DWH is now better understood.

This literature review is beneficial to researchers and scholars interested in the areas of PM and DWH since it presents the first study that systematically reviews the current literature on PM in DWH. Thus, it contributes to better understanding the current BOK in this field.

There needs to be new research in the field of DWH in PM.

It is discovered that the majority (11 out of 33) of identified studies are 10 to 15 years old. Fresh research is required in order to shed light on current advances in the field.

The review identified clear research gaps and provides a research agenda.

The results from this study give clear indications as to what fields in the area of DWH PM need more research and what fields have been (relatively) more extensively studied thus far. The heat map reported in Table 8 shows that the procurement management PMKA is notably unexamined, whereas, for example, the integration management PMKA has received significantly more study. If we focus on the second research dimension (DWH stage), it is clear from Table 6 that, even though the initial DWH stages (project initiation/planning and requirement analysis) have been the subject of research, other DWH stages have not been studied to the same extent. These later stages nevertheless represent important elements of DWH projects and are critical for their success.

Moving forward, researchers can focus their studies based on the proposed research agenda in Section VII.

APPENDIX A STUDIES SELECTED IN THE REVIEW

[S1] K. Ramamurthy, A. Sen and A. P. Sinha, "Data Warehousing Infusion and Organizational Effectiveness," *IEEE Transactions on Systems, Man, and Cybernetics - Part A : Systems and Humans,* vol. 38, no. 4, pp. 976-994, 2008.

[S2] S. R. Gardner, "Building the data warehouse," Communications of the ACM, pp. 52-60, 1981.

[S3] D. Sammon and P. Finnegan, "The Ten Commandments of Data Warehousing," *The Data Base for Advances in Information Systems,* vol. 31, no. 4, pp. 82-91, 2000.

[S4] D. Batra, "Agile values or plan-driven aspects: Which factor contributes more toward the success of data warehousing, business intelligence, and analytics project development?," *The Journal of Systems & Software*, vol. 146, pp. 249-262, 2018.

[S5] D. Batra, "Adapting Agile Practices for Data Warehousing, Business Intelligence, and Analytics," *Journal of Database Management,* vol. 28, no. 4, pp. 1-23, 2017.

[S6] X. Li, "Building an agile data warehouse: A proactive approach to managing changes," in *5th IASTED International Conference on Communications, Internet, and Information Technology*, St. Thomas, USA, 2006.

[S7] B. H. Wixom and H. J. Watson, "An empirical investigation of the factors affecting data warehousing success," *MIS Quarterly,* vol. 25, no. 1, pp. 17-32, 2001.

[S8] M. Golfarelli, S. Rizzi and E. Turricchia, "Modern Software Engineering Methodologies Meet Data Warehouse Design: 4WD," in *International Conference on Data Warehousing and Knowledge Discovery*, 2011.

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TABLE 10. Additional mapping with the research dimensions.

Study	Secondary DWH stage	Secondary PMKA elements
S1	None	Since organizational support is mentioned as one of the determinants that influences DWH infusion, stakeholder management should be planned for during the initiation and planning stages. These activities are part of the identify stakeholders [29, p. 507] and plan stakeholder engagement processes [29, p. 516], which are part of the stakeholder management PMKA. Since these are described in minimal detail **0.1** points is added in Table 8 to the **stakeholder management PMKA** in the **Project initiation/planning DWH stage.**
S2	The study addresses metadata management and its importance for the end user. Therefore, it should be planned for in the **requirement analysis stage**.	In this study, metadata is mentioned as an integral part of the DWH solution. This can be mapped to the quality management PMKA since the processes that address product quality requirements are managed in this PMKA [29, p. 271]. Metadata management can also be seen as *expert judgment* [29, p. 281] or as industry standard and best practice in DWH projects, and should hence be considered when tailoring the quality management processes [29, p. 276]. Additionally, metadata deliverables should also be addressed and planned for, during the requirements gathering phase, as both functional and nonfunctional requirements and quality requirements of the product [29, p. 148]. This is done in the requirements gathering process that is addressed in the scope management PMKA in the *PMBOK® Guide*. The paper provides a dozen use cases for metadata management it, however it does not provide any guidelines for PM, in the context of metadata management. Therefore, **0.1** points is added to **quality management** in the **Project initiation/planning DHW stage** and **scope management** in the **Requirements analysis DWH stage**.
S3	None	The study mentions the following project tasks as key prerequisites for the DWH implementation: (1) *A business-driven data warehousing initiative*; (2) *Executive sponsorship and commitment*; and (3) *Project team with access to cross-functional project management and implementation experience*. These prerequisites can be seen as *Industry-specific resources* that are required for DWH projects [29, p. 311]. Resource requirements, the way how to plan and manage them are covered in the *plan resource management*. [29, p. 312] and *estimate activity resources* processes [29, p. 320], which are part of the resource management PMKA. Since the details are described in minimal detail, **0.1 points** is added in Table 8 to the **resource management PMKA** in the **Project initiation/planning DWH stage**.
S6	Since the proposed approach should be applied throughout the DWH lifecycle, 0.1 points is added in Table 8 to the **integration management PMKA** to the **requirement analysis, database design, and production usage and maintenance DWH stages** as well.	The topic of proactive change management is in a way connected to risk management. Creating flexible processes, including change management processes is needed in order to increase the resilience of the project to possible threats [29, p. 399]. Therefore, 0.1 points is added in Table 8 to the **risk management PMKA** in the **Project initiation/planning DWH stage.**
S15	None	The findings from this study are also related to schedule management since EVM can be used to track schedule variances [29, p. 262]. Therefore, 0.25 points are added in Table 8 for the **schedule management PMKA in Project initiation/planning DWH stage.**
S16	The study addresses metadata management and its importance for the end user. Therefore, it should be planned for in the **Requirement analysis DWH stage**.	Metadata deliverables should also be addressed and planned for, during the requirements gathering phase, as both functional and nonfunctional requirements and quality requirements of the product [29, p. 148]. This is done in the requirements gathering process that is covered in the scope management PMKA. Therefore, **0.1** points is added in Table 8 to the **scope management PMKA** in the **Requirements analysis DWH stage.**
S17	Study provides a section on post-implementation recommendations in DWH projects. Therefore 0.1 points is added in Table 8 to the **quality management PMKA** in the **Production usage and maintenance DWH stage** as well. The study addresses metadata management and its importance for the end user. Therefore, it should be planned for in the **Requirement analysis DWH stage**.	This study also provides some summarized findings related to DWH projects in the context of obtaining approval and implementation challenges. Authors state that sponsorship should come from both IT and business departments. Interestingly, authors also mention some of the sources of opposition for DWH projects. Study also contains a section on recommended post-implementation activities in DWH projects. One of the key suggestions is to allocate time for constant training of business users in ways they can better answer business questions by using information form the DWH, but also in improving technical skills. Watson and Haley also state that power users end up providing most of the needed support for business users, which may reduce their available time for using the DWH. Both of these findings can be seen as general considerations for DWH projects, and in the context of the PMKAs as *an enterprise environmental factor*, i.e. *project management BOK from specific industries* that is incorporated into the PM plan [29, p. 84]. Hence, 0.1 points is added in Table 8 **in the integration management PMKA** in both the **project initiation/planning DWH stage** and **Production usage and maintenance DWH stage.** Metadata deliverables should also be addressed and planned for, during the requirements gathering phase, as both functional and nonfunctional requirements and quality requirements of the product [29, p. 148]. This is done in the requirements gathering process that is part of the scope management PMKA. Therefore, **0.1** points is added in Table 8 to the **scope management PMKA** in the **Requirements analysis DWH stage.**
S18	This study findings primarily describe testing in DWH projects in general and during the planning stages. However, there are additional considerations on how to test logical and conceptual schema, ETL procedures, database, and front-end tools. Therefore, 0.1 points is added in Table 8 to the **quality management PMKA** in the **Database design, ETL design, and Query/Reporting DWH stages.**	None
S19	The study addresses ETL and user testing by describing several techniques used and helpful practices during development. Therefore, the findings from this study can also be mapped to the **ETL design DWH stage.**	This study also contains a set of practices and lessons learned for ETL and end user testing. In the *PMBOK® Guide*, product testing is viewed as a tool and technique used during the plan quality and control quality processes [61, pp. 285, 303]. However, minimum background or elaboration is provided in this study, therefore, **0.1** points is added in Table 8 to the **quality**

TABLE 10. *(Continued.)* **Additional mapping with the research dimensions.**

		management PMKA in the **ETL Design DWH stage.** In one section, the study also provides a review of the planning approach applied throughout the project. Inputs from this study can be viewed as *expert judgment* from similar projects in the context of schedule development, management, and control [29, p. 181]. Since several techniques are elaborated on, but not in much detail, **0.1** points is added in Table 8 to the **schedule management PMKA** in the **Project initiation/planning DWH Stage.**
S23	The study addresses metadata documents and its importance for the overall process. Therefore, it should be planned for in the **Requirement analysis DWH stage**.	In this study, Shin also provided some minor suggestions in the context of metadata management. Shin stated that *poor metadata documentation and the lack of integrity in the source data in the form of missing values, overlapping values, inconsistently formatted values, and illegal values created tremendous overhead during data staging*. He also mentions that these issues caused a one-month delay on the planned 6 months project. This can be mapped to the quality management PMKA since the processes that address product quality requirements are managed in this PMKA [29, p. 271]. Metadata management can also be seen as *expert judgment* [29, p. 281] or as industry standard and best practice in DWH projects, and should hence be considered when tailoring the quality management processes [29, p. 276]. However, minimum elaboration or inputs on how the problem was solved was provided. Therefore, **0.1 points** is added in Table 8 to **the quality management PMKA** in the **Project initiation/planning DWH stage**. Metadata deliverables should also be addressed and planned for, during the requirements gathering phase, as both functional and nonfunctional requirements and quality requirements of the product [29, p. 148]. This is done in the requirements gathering process that is part of the **scope** mng. PMKA. Therefore, **0.1** points is added in Table 8 to the **scope management PMKA** in the **Requirements analysis DWH stage.**

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TABLE 11. List of identified stakeholders and their context from the literature review studies.

Study	Stakeholders identified	Context
[S1]	Senior management, internal and external DWH users, IT department,	Analysis of effects on DWH infusion,
[S3]	Business users, senior management champion, IT department,	Prerequisites for a successful DWH implementation,
[S7]	Management, champion, end-users, development team,	Analysis of factors affecting DWH success,
[S8]	End-users,	Testing and detecting errors in the DWH,
[S12]	Business users,	Involvement in the business process analysis,
[S13]	End-users,	Support and training,
[S16]	End-users,	Metadata documentation and management,
[S17]	End-users,	Metadata documentation and management,
[S20]	End-users and IT users,	Effects of joint IT-business competences and partnership,
[S23]	End-users,	Project organizational chart from a DWH implementation.
[S24]	Agile coach, and database administrators.	Lessons learned from an agile-driven DWH implementation.

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APPENDIX B

See Tables 10 and 11 here.

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