Digital Assets for Project-Based Studies and Project Management

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Abstract. This research provides a literature survey of digital assets available through a project; specifically, it identifies sources of data that can be used for practicing data-driven, context-specific project management, or for project-based academic research. Projects are key vehicles for economic and social action, and they are also a primary source of innovation, research, and organizational change. The project boundaries of time, tasks, and people define a rich environment for collecting behavioral and attitudinal data for learning opportunities and academic research. Based on a systematic literature review of the top four project management journals, this research identifies four categories of data sources – communications, reports/records, model representations, and computer systems – and 52 digital assets. The list of digital assets can be inputs for the creation of project artifacts as well as sources for monitoring and controlling project activities and for sense-making in retrospectives or lessons learned. In an illustrative case, this research uses three of the digital assets, social network analysis, and topic modeling to analyze the verbal and written communications between project participants. The classification model and categorization are useful for decision support and artificial intelligence systems model development that requires real-world data.

Keywords: Digital asset · Project management · Project studies · Big data

1 Introduction

Projects offer rich environments for conducting research and learning [1, 2] and for practicing data-driven, context-specific project management [3]. They are a key vehicle for economic and social action, as well as a primary source of innovation, research, and organizational change [4–6]. They can involve budgets larger than the gross domestic product of a small nation and resources greater than the organizations participating in them [1]. Some of the factors that make projects interesting for analysis through a multitude of theoretical lenses are the scale, complexity, uncertainty, and geographic distributions [6]. Projects can be explained and studied using philosophical underpinnings (such as the Newtonian understanding of time, space, and activity) through the project archetypes such as project-based organizations, project-supported organizations, and project networks, or through the investigation of the changes in project processes or actors [4–6].

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The variety and richness that make projects interesting to study, however, can make them a challenge to manage efficiently. First, there are many project-specific tools and techniques available to manage project complexities [7, 8]. Muszyńska and Swacha [8] highlighted multinational, dispersed teams, and the need for a different tool selection for each unique project as some of the factors that make projects complex. Second, the tens of project management suites and tools available demonstrate the many factors that managers must consider when planning, monitoring, and controlling projects [7–9]. Third, although collecting lessons learned and implementing improvement processes are central concepts in project management standards [10–12], the learning rarely happens or does not deliver the intended results [13]. Finally, the administration of projects is moving away from paper documents to a new way of managing task infrastructure through digital information [14].

Researchers have begun to argue that real-time project data should be used in stakeholder engagement [15], performance management [3, 16, 17], monitoring and controlling [18], and policy setting. These approaches support project management moving from individual human-based decisions to expert decisions to utilizing artificial intelligence. For example, Snider, Gopsill, Jones, Emanuel, and Hicks [3] argue that project performance should be evaluated based on an analysis of the data artifacts produced from everyday project activities rather than by relying on managerial understanding. Nemati, Todd, and Brown [19] explain that project estimation is suitable for an artificial neural network given the numerous potential project configurations. Willems and Vanhoucke [18] found that artificial intelligence was used at the front-end of projects but suggested its use has been less investigated during projects. The transition to these data-driven methods is supported by the growing importance of digital workflows and analytics in project delivery [14].

Therefore, even though projects are rich grounds for research and the push towards data-driven project management, the topic of digital data—structured and non-structured—in projects is not sufficiently covered in project management literature. This research involves a systematic literature review to compile a list of digital assets available through a project context. A digital asset classification would be valuable to project researchers and to project managers for practicing data-driven, context-specific project management, or for project-based academic research. Thus, the study uses a conceptual model that presumes digital assets are sources of learning. While there are individual studies that provide some insight into the sources of project management data and while the project management standards provide document lists, there is no comprehensive list of project-specific digital assets available in the literature. Furthermore, this study supports the call for new research approaches that investigate the actual or lived experience [2].

The paper is structured as follows. Section two provides a literature review. Section three includes the conceptual framework and a description of the research methodology. Section four defines the classification model and describes its characteristics. Section five discusses the model and section six provides the study’s contribution, implications, limitations and consideration for future research.
2 Literature Review

2.1 Project Management Tools

Projects are a temporary organization with a set of actors working together over a limited, pre-determined period of time for a given activity [1]. They can vary in size and scope from organizational projects to programs used to transform society. There are hundreds of project management tools and tens of software suites available to manage the complexities created by the unique project environments. Project management tools include methods, decision-making techniques or models, risk assessment tools, information communication technology support tools, computer models, databases, indices and simulations [7–9, 20, 21]. Online collaborative toolsets allow project-related material to be customized for specific project roles and made available to multiple teams across multiple sites and countries [14]. Tool diversity, lack of use, limited feature coverage, and role distribution are some of the limitations that prevent project management tools and systems from being a single source of data for project research. Furthermore, the extent of use of the tools varies by the type of project deliverables. Finally, while databases of historical costs, lessons-learned, and risks from past projects are perceived to be of great value, they are some of the least-used tools [7].

2.2 Lessons Learned

In the available literature, organizational learnings rarely occur or deliver their intended results [13], and project management lessons learned are ineffective, incomplete, and ill-conceived [13, 22]. Consequently, there has been a call for an improvement in project management processes and methods for disseminating organizational learnings. For example, the Syllk model is useful for identifying needed improvements but not for making the underlying changes to policies, systems, and processes [13]. The triple-loop learning model combines individual, project, and organizational learning processes to react to the changes needed to embed learnings into an organization’s policies, standards, and practices [22]. However, the reality is a minority of organizations identify and capture lessons learned through formalized procedures. Moreover, knowledge is subjective and dependent upon the individual. The more successful individuals are at learning and retaining the learnings, the more difficulty they have in relating the salient knowledge to their peers [22, 23]. Specifically, knowledge is a driver for organizational success [24]. Capturing knowledge through digital data is commercially important and supports the trend towards using artificial intelligence and traditional statistical methods to solve project management problems [3, 18, 25].

2.3 Digital Data in Project Management

Quinton and Reynolds [26] defined digital media as encompassing “all computer-mediated internet and digitally-enabled media through which data may be collected, shared and/or analyzed…” [26, p. 11]. They described digital data (without providing a formal definition) as data available through digital technologies. Snider, Gopsill, Jones, Emanuel, and Hicks [3] limited their definition of digital data to engineering data
produced from every-day project activities. Whyte [14] determined that digital information permits the introduction of collaborative project delivery models with configurable supply-chains and relationships. In these new models, project teams are contractually obliged to deliver digital information to the long-term owner or operator. The study identified the convergence of digital information and project practices as a future area of research.

2.4 Summary

In summary, projects are important vehicles for delivering economic value. They can be complicated and can require managers to select from a variety of tools and methods for their efficient management. However, projects can also produce valuable digital data and individual and organizational learnings. While project contexts are promising for research, integrating individual learnings into organizations is difficult. For this study, we define a digital asset as any digital data that may be used for analysis using computer technology. Digital assets are an increasingly valuable way of accessing project learning. Furthermore, they are useful as a foundation for project management decision-making and artificial intelligence systems. However, there is a gap in providing a comprehensive list of digital assets available from a project context. The objective of this study is to compile a survey of digital assets available through a project-context that can be used for research and for moving towards data-driven project management.

3 Research Methodology

First, we provide a conceptual model for investigating the topic. Next, we described the systematic literature review and illustrative case methods used in the study. Finally, we explain the measures taken to ensure validity and reliability.

3.1 Conceptual Model

The conceptual model for this study builds on theories from organizational learning and concepts from the triple-loop learning model [22]. The triple-loop learning model aligns the project, process, and organizational learning perspectives with the planning, delivery, and temporal phases of a project. Each learning loop considers a targeted outcome against which project variances are evaluated. Understanding and investigating variances produces learnings. Learnings may be incorporated into processes, procedures, or other project objects based on decisions and reactions to the variance. Learning goals are defined and further project actions are taken.

The conceptual framework from this study presumes that the source of learning is the digital asset. Figure 1 demonstrates the conceptual model for the relationship between digital assets and project artifact. Digital assets are used and are generated at all stages of the project (as are project inputs and outputs) and may undergo transformation at any stage. The optionality of the analysis is shown in Fig. 1 as a dotted line. The digital assets may provide raw data such as historical records as inputs into the project. The project artifacts may themselves be digital data that result from project work. Learning occurs
through the project work as well as through investigating and understanding variances that may result in digital assets that are provided to project to produce project artifacts such as lessons learned documents or process improvements. Furthermore, the learnings may result in revisions to practices, models, or project artifacts.

The research methodology consisted of using a systematic review of the literature to compile the digital assets classification and an illustrative case to validate its relevance. “A systematic review is a review of a clearly formulated question that uses systematic and explicit methods to identify, select, and critically appraise relevant research, and to collect and analyze data from the studies that are included in the review” [27, p. 336]. A practitioner researcher-led case study was used to verify the relevance of the digital assets in projects.

3.2 Systematic Literature Review

**Research Question.** The research question for the systematic literature review is what digital assets are available through a project context? Thus, bodies of knowledge from the project management domain were selected to place boundaries around the research.

**Keyword Selection.** A literature review was performed to identify and classify digital assets in a project context. The project management bodies of knowledge that are used worldwide were reviewed to identify the project artifacts that could be digital assets: “ISO 21500:2012, Guidance on Project Management” [12], APM Body of Knowledge 6th Edition [11], A Guide to the Project Management Body of Knowledge (PMBOK guide) 6th Edition [10], and PRINCE2 [28]. Although criticized by some researchers, the “standards have come to represent an institutionalized collective identity of project managers” [29, p. 37]. Therefore, they offer guidelines for identifying project data sources. From the list of project artifacts, the keywords for the file content and knowledge areas were compiled into a list.

**Article Selection.** The main research journals that focus on project management [2] (i.e., Project Management Journal [PMJ], International Journal of Project Management...
[IJPM], and IEEE Transactions on Engineering Management [IEEE] [2] and International Journal of Managing Projects in Business [IJMPB]) for the years 2000–2020 were selected for the keyword search. The bibliographic data from these journals were downloaded from the Emerald, ScienceDirect, IEEE Xplore, and Sage databases into the Endnote reference system. A set of search queries were created for each project management knowledge area keyword. Each query included the selection criteria for any keyword in the data type from the file abstract, any keyword in the file content from the abstract, and any keyword for that knowledge area from the title. An additional query set included any article with the word “digital” in the abstract, title, or keyword. Table 1 includes the keyword list that was used to perform the systematic review. The cumulated search queries produced a list of 360 unique articles. Given that each project management journal was sourced from a different database, no duplicate records were found or removed.

| Search topic | Keywords |
|--------------|----------|
| Data type    | Image, text, numeric, static, dynamic, artificial, tool |
| File content | Register, report, data, calendar, file, list, system, log, estimate, forecast, brief |
| Procurement  | Procurement, contract, legal, law, supplier, vendor, contractor |
| Financial    | Financial, cost, budget, estimate, forecast, business case |
| Schedule     | Calendar, schedule, milestone, duration, time, activities |
| Scope        | Requirement, scope, assumptions, feature, user story, specification, acceptance |
| Resource     | Resource, team, people, competence, competency |
| Risk         | Risk, uncertainty |
| Integration  | Change, configuration, control, life cycle, methodology, integrate |
| Communication| Communication, coordination |
| Stakeholder  | Stakeholder, sponsor, owner, investor |
| Quality      | Quality, test, evaluation, traceability |

**Article Screening.** The abstracts for the selected articles were reviewed to determine if the article described the content or production of a digital project artifact. Based on the abstract review of the 360 articles, 99 articles were potentially relevant to the research topic. The full-text review produced 49 articles that described digital assets in sufficient detail to support the classification. To be included, the digital assets had to be a file or data item that could be 1) accessed by or created by a project actor or action, 2) be described in enough detail to determine its classification characteristics, and 3) be relevant to at least one of the project management knowledge areas. Based on observation, some items were included whenever a digital trace could be identified. For example, a case study that
described an interview (which falls into the observation category) would normally be excluded; however, if a case study described a recording or transcription of an interview, the recording was included in the classification model. Table 2 provides an overview of the number of articles extract per journal and analysis stage. The classification details for the articles and digital assets are provided in the next section.

**Coding Strategy.** The coding strategy used to identify and classify digital assets was customized from the classification categories provided by [3, 26, 18]. In [3], digital assets were classified as digital communication between actors, virtual representations and models of project objects, or textual or numerical documents. That study created decision support monitoring processes based upon the physical attribute (e.g., size or dates), content or context (e.g., origin, project stage) of the digital asset. Those attributes were not considered in this study.

Quinton and Reynolds [26] specified the dimensions of the data, including data type (attitudinal or behavioral), distances from the data source (primary or secondary), data generation (mythically manufactured or naturally occurring), and data visibility (public or private). They also specified the characteristics of the dataset (big data, open data), the information (encoding format, provider), usage, and ethical challenges. In this study, we grouped digital assets using the data dimensions from [26] as well as attributes from our conceptual model.

Willems and Vanhoucke [18] provided a framework for describing the articles that added richness to their classification model on project control and earned value management. Their framework included the journal, research problem, contribution, methodology, analysis, and application of the paper. We analyzed the journal, methodology, data collection method, and analysis for each article used in the classification model.

After collecting and reviewing all articles within the defined scope, we compiled a list of digital assets that met the criteria and developed the classification framework for the articles and for the digital assets.

### 3.3 Illustrative Case Study

Case studies are a method of connecting qualitative understanding with issues, situations, and actions occurring in projects [30]. The case study method is consistent with the recommendation that practitioner-researchers familiar with scientific research and the professional practice should contribute knowledge to the project management discipline [31]. Furthermore, the case study approach provides multiple sources of evidence—archival records and participant observation [32]. This study included an illustrative case that involved extracting email and calendar data from Microsoft Outlook into Excel using a Visual Basic macro. The data were combined with the project contact list to identify roles and standardize the data. The data were anonymized in Excel. The Excel data were imported into R Studio version 1.3.1073 for analysis. Social network analysis, topic modeling, and reporting functions were used to analyze the data and present the results for the study. Detailed statistics are not reported in this study because the goal of the illustrative case was to demonstrate the use of digital assets from projects.
Table 2. Number of journal articles by stage

| Journal | Total articles | Screened articles | Full-text review | With digital assets |
|---------|----------------|-------------------|------------------|---------------------|
| IEEE    | 1401           | 124               | 35               | 17                  |
| IJMPB   | 644            | 54                | 14               | 5                   |
| IJPM    | 1918           | 139               | 38               | 19                  |
| PMJ     | 1080           | 43                | 12               | 8                   |
| **Total** | **4414**      | **360**           | **99**           | **49**              |

3.4 Validity and Reliability

Validity refers to the extent to which the items are comprehensive and representative of the expected concept. Reliability estimates the degree to which the results are not random and free from unstable errors and reflect what is intended. The following steps were taken to ensure content external validity, internal consistency, relevance, and reliability. First, a conceptual model was designed through the theoretical lens of organizational learning and concepts from the triple-loop learning model [22]. The theories provided a framework for the use of data in defining learning goals and furthering project actions. Next, a systematic review was used to identify digital assets. The project management standards were used to identify keywords relevant to project management subjects. The keywords guided a systematic literature review of the dominant project management journals. Next, the coding strategies followed classification models for digital assets from research and project management [3, 18, 26]. The steps ensured the internal and external validity of the model. Finally, the research methodology used to define the classification model is documented in a manner that includes replication logic. The 27-item checklist and a four-phase flow from the PRISMA Statement were used to guide the study and report the results [27]. Care was taken to fully document the search process and the inclusion and exclusion criteria to support repeatability [33].

4 Research Findings

The articles from the systematic literature review were processed to identify digital assets available in a project context. Each digital asset was described and classified using the characteristics detailed in this section.

4.1 Classification Framework

The following characteristics were identified for each digital asset. The abbreviations presented here are used in the tables that describe the artifacts.

1. The category combines the digital assets into four groups: the communication between actors; virtual representation or models; and records and reports; and systems. The research found that the digital assets are embedded in computer systems
such as Computer-aided design (CAD), Geographical Information System (GIS), project management information system (PMIS), patent database, project scheduling, social media applications, virtual meeting platforms, or virtual reality technologies. The data that can be extracted as exports, database transactions, or tabular records from such systems are classified in the study [8]. Tables 3, 4 and 5 include the classification details of the assets by category.

2. The **digital asset** is a descriptive name for the data artifact.

3. **Data type** (DT) identifies the data as attitudinal or behavioral. Attitudinal data describes what people say, behavioral data describes what people do, or mixed.

4. The **data source** (DS) identifies the items as a primary source where raw data can be collected with a specific question in mind (e.g., an email) or a secondary source where the data has already been filtered or interpreted by someone like the project manager (e.g., a status) or a model.

5. **Visibility** (VIS) identifies the location and ownership of the data. The options include public, private, or open. Public data are accessible from a public location within the project environment; however, there may be access controls or restrictions; private data are confidential to a specific individual or group; open are public data from a public source such as local or government projects.

6. The **encoding** identifies the format of the data. The data can be text, numeric or relational data, images or spatial data, videos or audio, or a mixture.

7. The article **reference** (Ref), **analysis methods** (Anal), and **project artifact** characteristics are given in the next sections.

### 4.2 Article Reference

There were 49 articles that described the input or outputs of project activities, digital project artifacts, or digital assets used in project research. The article reference is indicated for each of the digital assets. The articles approached the research population using statistical methods (Stat), case studies (CS), experiments (EXP), or literature reviews.

| Asset                  | DT | DS | Vis | Encoding          | Anal      | Project artifact | Ref(s) |
|------------------------|----|----|-----|-------------------|-----------|------------------|--------|
| Contact lists          | A  | P  | Private | Video, audio, text | Stat     | COMM             | [34]   |
| Email - private        | A  | P  | Private | Text              | Stat      | SE               | [16]   |
| Email - public         | A  | P  | Public  | Text              | Obs      | TE, TML          | [35]   |
| Media                  | A  | P  | Open   | Video, audio      | Txt      | IL               | [36]   |
| Meeting reports        | A  | S  | Private | Text              | Txt      | IL               | [36]   |
| Newspaper articles     | A  | P  | Open   | Text              | Obs      | FB               | [37]   |
| Parliament proposals   | A  | P  | Open   | Text              | Obs      | FB               | [37]   |
| Public comments        | A  | P  | Open   | Text              | Comp     | SR               | [38]   |
| Recordings             | M  | P  | Private | Video, audio      | Obs      | TE               | [39]   |
| Social media groups    | A  | P  | Private | Video, audio, text | Stat     | COMM             | [34]   |
| Virtual meetings       | A  | P  | Public  | Video, audio, text | Txt      | AL               | [40]   |
### Table 4. Digital assets—virtual representations

| Asset                                | DT | DS | Vis    | Encoding | Anal | Project artifact | Ref(s) |
|--------------------------------------|----|----|--------|----------|------|------------------|--------|
| 3-d or 4-d diagrams                  | B  | P  | Public | Image    | Obs  | TE               | [39]   |
| Aerial images                        | B  | P  | Public | Image    | Comp | RR               | [41]   |
| Artificial intelligence models       | B  | S  | Private| Numeric  | AI   | FC               | [25, 42]|
| Building information modelling       | B  | P  | Public | Relationaldata | Obs | PSCH            | [43]   |
| Competency matrix                    | B  | S  | Public | Text     | Obs  | RREQ             | [44]   |
| Earned value model                   | B  | S  | Private| Relationaldata | Obs | FC, EVMGT, RR, FS | [45]   |
| Engineering change proposal          | B  | P  | Public | Text     | Comp | RR, CE, DE, PS  | [46]   |
| Mathematical models                  | B  | S  | Public | Numeric  | Stat | RREQ            | [47, 48]|
| Matrix                               | B  | S  | Private| Relationaldata | Comp | TS, AN         | [49]   |
| Network model                        | B  | S  | Public | Relationaldata | Stat | RR             | [50]   |
| Sensor data                          | B  | P  | Public | Relationaldata | Stat | AC             | [51]   |
| Spatial data                         | B  | P  | Public | Spatial data | Comp | PSCH         | [52]   |
| Time-based activity network          | B  | P  | Public | Text     | Stat | TAS            | [53]   |
| Virtual reality models               | B  | P  | Private| Video, audio | Obs | TE             | [39]   |

(LR). Statistical methods used a large sample from the population, case studies focused on understanding a few cases in detail, experiments were situations manufactured by the researcher, and structured reviews were topical studies from journal articles or other secondary sources. The data collection method defines the type of data that was used as a research or validation data source in the article; the definitions follow a model from [18]. Historical real-world data (Hist) are results from actual projects. Simulated-data (Sim) are generated from a simulation method such as a random sample. Qualitative data (Qual) represent an illustrative case or a single project case study.
Table 5. Digital assets—reports and records

| Asset                                | DT | DS | Vis  | Encoding     | Anal | Project artifact | Ref(s) |
|--------------------------------------|----|----|------|--------------|------|------------------|--------|
| Academic literature                  | A  | S  | Open | Text         | AI   | SSL              | [54]   |
| Budget                               | B  | S  | Private | Relational data | Obs | FB               | [37]   |
| Charts - graphs - drawings           | B  | S  | Private | Image      | Comp | PSCH             | [52]   |
| Chronological database               | B  | S  | Public | Text       | Obs  | SR               | [15]   |
| Configuration commit                 | B  | P  | Public | Text       | Stat | CI               | [55]   |
| Database transaction                 | B  | P  | Private | Relational data | Obs | FC, EVMGT, RR, FS | [45]   |
| Fact sheets or annual reports        | A  | S  | Open | Text        | Stat | IP               | [56]   |
| Integrated master plan               | B  | S  | Public | Text       | Obs  | PSCH             | [57]   |
| Item metadata                        | B  | P  | Public | Text       | Stat | AN               | [3]    |
| Patent documents                     | A  | P  | Open  | Text       | Stat | PS, FC           | [58]   |
| PMIS-task assignment                 | B  | P  | Private | Relational data | Obs | TAS              | [59]   |
| PMIS-time-tracking                   | B  | P  | Private | Relational data | Obs | TAS              | [59]   |
| Project documents                    | M  | S  | Public | Text       | Comp | QM               | [42]   |
| Resource allocation database         | B  | P  | Private | Text       | Obs  | RC               | [60]   |
| Schedule and cost forecast transactions | B  | S  | Private | Relational data | Obs | FC, EVMGT, RR, FS | [45]   |
| Searchable document database         | M  | P  | Public | Text       | Obs  | CT               | [14]   |
| Survey responses                     | A  | S  | Public | Text       | Stat | AC               | [51, 61] |
| Tabular                              | B  | S  | Private | Relational data | Stat | RRPT             | [61]   |
| Technical reports                    | M  | S  | Private | Text       | Comp | RR, CE, DE, PS   | [46]   |
4.3 Analysis Methods

Type of analysis describes the techniques the article used for analyzing data in three broad categories: observational, computerized, and statistical. These definitions extend the model created by [18]. Observational analysis (Obs) includes data from literature surveys or empirical investigations; computerized analysis (Comp) includes automated systems or automated processes; statistical analysis (Stat) includes mathematical, network, or other analytical modeling methods; artificial intelligence (AI) includes methods that learn from experience and apply the learning to new situations; and text analysis (TXT) includes methods that analyze words or phrases from free-text.

4.4 Project Artifacts

The project artifacts that were inputs to or outputs from digital assets were documented in the classification model. Since the papers used a variety of names to describe similar content, artifact names from the project management standards were used whenever possible. In this section, the description of the artifacts is consolidated into a synthesis of the knowledge area from the project management standards [10–12, 28].

The integration knowledge area includes artifacts and processes that unify, consolidate, and integrate work across different areas [10, 12, 28]. A change log (CL) is a list of alterations submitted during the project and their status; it is used to communicate change requests to the impacted stakeholders. A change request (CR) is a proposal to modify a previous agreement for producing a work product, document, deliverable, or other work items. An issue lists (IL) is a catalog of unexpected events, problems, or tasks that are present in a project, and action must be taken to address the topic. The lessons learned register (LL) is the result of a project learning and may be produced as the result of a post-project or retrospective review.

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The scope area includes artifacts to control what will and will not be included in the project work and may be defined by a business case [10, 28]. Requirements describe the needs of the customer and the acceptance criteria (AC) describe the performance indicators that will be used to judge success. The product specifications (PS) identify the customer’s requirements and design parameters or attribute alternatives, including critical parameters such as materials, dimensions, product and process technology, testing, and the number of possible changes. The configuration item (CI) is a file that represents the basic unit of work in software engineering projects. Work breakdown structure (WBS) is a hierarchy-based list of all the work to be executed by the project team to create the necessary deliverables and meet the project objectives.

The financial and cost management artifacts include the monetary considerations needed to justify and control the project costs [11]. The forecasts include financial forecasts (FF) for the monetary costs at completion and include measures necessary to monitor the financial performance of the project. The financial costs (FC) identify where and when costs will be expended. The earned value method (EVM) is a typical method used to forecast and monitor project schedule and cost performance. The estimates include cost estimates (CE) for the total monetary costs for the project; duration estimates (DE) for the overall project, task, or change duration; and effort estimates (EE) for the amount of work.
Activity lists, activity networks, duration estimates, and schedules are artifacts identified in the schedule knowledge area, which focuses on the timely delivery and use of resources [10]. The project schedule (PSCH) is a date-based activity-level list that provides the basis for assigning resources and developing the budget. Schedule forecasts (FS) estimate the completion dates. The activity list (AL) is a breakdown of tasks or activities required to produce the project’s work products or otherwise meet the project objectives.

The resource management knowledge area focuses on having the right people and material available [10, 12]. The resource requirements (RREQ) identify the labor, material, equipment, and supplies needed for the project activities and work products. The resource calendar (RC) identifies when each specific resource is available; it may include the availability by day of the week, hours per day, working times, shifts, public holidays, vacations, etc. The team assignment (TAS) identifies tasks and persons, groups, or organizations responsible for the tasks. The team member list (TML) identifies the people that are assigned to the project. The team structure (TS) depicts the hierarchy and relationship of the team members or the entire project organization.

The risk artifacts focus on managing the positive and negative uncertainty in the project [10–12, 28]. The risk register (RR) is a structured record, list, or document that details the identified uncertainties and their characteristics. The risk report (RRPT) provides risk status (RS) and summary information on the project risks and is used to communicate with the impacted stakeholders.

Project communications include the exchange of information between the project, its stakeholders, and team members [10, 12]. The communications are focused externally outside the project as stakeholder engagement (SE) or within the project as team engagement (TE). The stakeholder register (SR) contains details of the entities with interest in the project or its outcome, and it provides an overview of their roles and attitude toward the project.

The procurement knowledge area is centered around the contract and legal concerns and supplier management [10, 11]. A contract (CT) is an agreement reached between parties with the intention to create a legal relationship that protects the interests of the parties for consideration or understanding of an exchange of benefits and losses. Intellectual property (IP) are outcomes of the project that result in intangible products such as licenses, patents, brands, etc. The selected supplier list (SLR) includes preferred suppliers or contractors that were evaluated based upon established criteria and selected to provide products or services to the project.

Quality measures (QM) are performance metrics or measures that evaluate the performance of the project or the quality of the delivered product [10, 28].

4.5 Illustrative Cases

As an illustrative case for using the classification model, two questions were asked as a retrospective review of the case study project: Are we communicating enough with our stakeholders, and are we discussing the right topics? The research article from [62] were used to place boundaries around these two questions. The article identified factors frequency, content, and medium of communications between the project manager and the sponsor. The digital asset classification model identified email and meeting reports
as being related to stakeholder engagement [16, 36] and the contact list and social media as related to communications. The researcher having access to project artifacts as the responsible project manager chose to use personal email and calendar transactions and the project contact list to address the questions. Meeting reports were distributed through email so were indirectly part of the analysis. Social media was not used during the project.

The subject, sender, receiver, and date were extracted from emails, and the subject, attendees, location, and date from calendar meetings were extracted from Outlook to an Excel file. The contact list for the project was used to assign each message sender and receiver and meeting participant with an organizational level and project role. Personal identification information was removed from further processing.

For the analysis of communication frequency, frequency counts were computed and coded as follows: daily, weekly, monthly, at milestone, at phase end, and ad hoc. For the analysis of the communication mediums, “written” was used for email, and “verbal” was used for calendar meetings. Face-to-face interactions were not considered since the project was conducted in 2020 (i.e., during the COVID-19 pandemic). For the analysis of the communication content, text mining was used on the email and calendar subjects. Specifically, topic modeling created categories of topics based on words in the email or calendar subject. For reporting in this study, the topics were manually identified in some categories from [62]: status, issues, next steps, work products and others.

Table 6 includes the selected communication patterns for written communications and Table 7 for verbal. The project was conducted between May and August-2020, lasting for approximately 13 weeks. It had seven phases and four milestones. There were 48 people in written communication with 8 different roles. The sponsor is one member of the steering committee (SteerCo) role. In verbal communication, 37 people were involved in 9 roles. The communication pattern suggests the project work product content was discussed with the sponsor when needed and through written communications, and weekly verbal meetings were used for status updates. While this communication pattern does not neatly fit with the frequency for content factors from [62], it does reveal that the sponsor was sufficiently engaged. In summary, the digital data assets used in this illustrative case answered key questions about the project execution. There are possibilities for analysis of communication patterns described by [9], which is currently beyond the scope of this case. Conversely, there are limitations created by the need to remove personally-identifying information to protect individual privacy.

| Role          | Email communication pattern                       | Mail theme          |
|---------------|---------------------------------------------------|---------------------|
| Supplier      | Adhoc + Some phase ends + Some milestones         | Issues or open items|
| SteerCo       | Adhoc + Some phase ends + Some milestones         | Work product        |
| Team-functional | Adhoc + Some phase ends + Some milestones          | Work product        |
Table 7. Selected verbal communication patterns

| Role               | Calendar communication pattern                                      | Main theme   |
|--------------------|---------------------------------------------------------------------|--------------|
| Supplier           | Weekly + Some phase ends + Some milestones                          | Next steps   |
| SteerCo            | Weekly + All phase ends + Some milestones                           | Status       |
| Team-functional    | Weekly + Some phase ends + All milestones                           | Next steps   |

5 Discussion

This collection of data assets identified in this study underscores the variety of content, and consequently, management challenges that are inherent in projects. It validates some of the proposed use cases for digital assets and uncovers where value may be found in the digital assets.

The 11 items for communication category between actors represent textual documents or video or audio recordings that capture the attitudes of individuals and organizations. In most cases, they represent a primary source of data that can be analyzed using a multitude of analysis methods such as network analysis, statistics, or text mining. The strong showing of assets in the communication category support the argument made by [8] that communication software is important in project realization environments. Conversely, the variety of sources suggest that software is only one tool for understanding communication patterns. Additional assets such as email, meeting reports, or public documents should be used in the analysis of communication frequencies or analysis of any of the 11 project communication patterns identified by [9]. However, one of the challenges in accessing and analyzing communication data is preserving privacy and compliance with privacy laws [26, 51, 63].

The reports and records category of 19 items is a mixed bag where it is more likely that the acts and actions within a project can be analyzed. Many of the assets could be extracted from project management software or databases. However, digital traces of actual behaviors are also available in open source or other non-traditional locations. For example, [53] analyze configuration commit metadata of an engineering design process data of a biomass power plant to determine team assignment.

The virtual representation and model’s category introduced 14 data assets that all focus on behavior. This is a category of non-traditional project management data sources such as 3D and 4D models, spatial data, and other virtual models. The analytic methods in this category tend toward virtual and visual methods. For example, [41] used drones to capture aerial images of a small tank farm in Termini Imerese, Italy, to create a risk register. Cheng and Roy [25] and [54] used simulated or linguistic data to create artificial intelligence models that are characterized in the model as digital assets.

The final group is computer systems, databases, and applications that generate the data. Of the 8 assets identified, three are traditional project management systems, according to the details from [8]. However, building information systems that use spatial data and 3D and 4D diagrams in preparing project schedules are a modern development in construction project management [52].
From the project management knowledge area perspective, the quality, scope, and stakeholder areas were represented by the fewest number of assets and communication, schedule, and integration by the most. However, the financial and integration areas were the most dynamic with artifacts in all four categories. Example uses of assets for integration include the experimental use of virtual reality and recordings as digital boundary objects [39] or innovation cases where 3D and 4D diagrams are used to define team structures and activity networks [64]. Both the stakeholder and the risk knowledge areas used project and other documents for building stakeholder and risk registers [15, 65].

The articles used to compile the asset list offer examples of how data is used to analyze behaviors and attitudes. Furthermore, the existence of the assets may provide an input into the activity monitoring. Snider, Gopsill, Jones, Emanuel, and Hicks [3] described four monitoring use cases for digital assets, including monitoring communication trends coordinated with the project schedule, predicting time-to-completion, and identifying system and module dependencies. The case illustrated in this study demonstrate that the everyday project activities of scheduling meetings and sending emails provide an operationalized view of trends and gaps in communication. This confirms that project performance can be evaluated from an analysis of the data.

There are two benefits the digital assets offer for academic research and to project lessons learned. They make the knowledge objective and independent of individual memories or recalls. This removes human cognition and social interactions from the data collection process, which moves from self-reports to objective observation. Second, it avoids bias in the data due to individuals moderating their behavior due to observations. It does, however, introduce other issues such as gaining access to the data and overcoming privacy and ethical concerns [26, 51, 63]. Nevertheless, the digital assets provide the benefits of direct measurement that is less intrusive than other approaches such as surveys [24, 26].

The identification of assets, such as the use of spatial data and 3D and 4D models, highlights that the data generated are not just one-dimensional that have value during the project but are also items that can provide value after the project is completed. The assets are also not only inwardly focused. For example, [58] used the patent database to define a product specification in the thin film transistor-liquid crystal display market that would be financially lucrative. This can explain why [14] determined that in new digital project models, project teams are contractually obliged to deliver digital information to the long-term owner or operator. Similarly, [24] detailed the competitive advantages derived from using computer systems for knowledge sharing between consumers and organizations; similar, benefits would apply to knowledge exchange between stakeholders and projects.

The study identified the convergence of digital information and project practices as a future area of research.

6 Conclusion

Projects involve a variety of tools, methods, and systems for their efficient management. Consequently, they produce valuable digital data and individual and organizational learnings. The research identified four categories and 52 items of digital assets that are
available throughout projects. The assets provide a source for primary and secondary data and can be used for project studies or for creating data-driven project management processes. Furthermore, they are useful for research and integrating individual learnings into organizations, accessing project learning, and providing a foundation for project management decision-making and artificial intelligence systems. The illustrative case provided an example for using readily available digital information to provide transparency and learnings from project actions.

6.1 Contribution to Knowledge

By consolidating the list of digital assets, this study contributes to the project management literature on communications, lessons learned, and digitalization. This digital asset classification fills a gap in the literature by providing a comprehensive list of digital assets available from a variety of project contexts. This work extends the examples of digital assets provided by [3]. There has been a call for an improvement in project management processes and methods for disseminating organizations’ learnings. The model should help reveal new possibilities for analysis to make project management lessons learned more effective, complete, and structured [13, 22]. Moreover, it provides a platform for moving knowledge from the subjective to the objective and reducing the dependence on only individual learnings [22, 23]. Finally, this research fits into the trend of using artificial intelligence and traditional statistical methods to solve project management problems [3, 18, 25]. Specifically, artificial intelligence is usually realized through the development of algorithms and models that require training data. The digital assets identified herein may be the sources of that data.

6.2 Implication for Practice

The practical implications are a list of digital assets that can be inputs in the creation of project artifacts and sources for monitoring and controlling project activities and for sense-making in retrospectives or lessons learned. Moreover, this categorization is useful for decision support and artificial intelligence systems model development that requires raw data. For example, [17] provided models for using social networks to improve project management performance and the illustrative example provided a method to extract social network data from project communication artifacts. Next, collecting lessons learned and the analysis and synthesis of team behaviors and attitudes are also possible by using the complication of digital assets. This should support implementing improvement processes as promoted by the project management standards [10–12, 28]. Finally, the digital assets themselves are valuable work products that can provide contractual value to project clients and sponsors, as argued by [14]. However, the project size, team competency, or project manager capabilities will be factors that determine the availability of data, and the need and ability to use digital assets in a project situations or research studies. Therefore, the digital assets proposed by the study may be too sophisticated for routine usage.
6.3 Implication for Research

Projects offer a rich environment for the time and actors, which are usually fixed at the start of the project. Thus, they are ripe for applying multiple research methods such as action research, case studies, and experiments. Digital assets support tracing individual, group, and organizational behaviors. Furthermore, digital data are especially relevant as organizations transition to digital and remote working environments. This categorization offers academic researchers a catalog of data sources and analysis methods for studying complex project phenomena. However, there may be some challenges in gaining permission and clearance to utilize the data in the desired method. In addition, ethical use is a concern when dealing with data related to individuals [26].

6.4 Limitations and Further Research

This research was based on a systematic literature review at a single point in time and focused on a small selection of publications. The journal selection was limited to the main project management research journals identified by [2]; however, other data sources may have produced a wider or different selection of digital assets. The contribution was made by an individual researcher; this approach may have limited the identification of digital assets based on the knowledge or biases of the researcher. Furthermore, the research did not consider project size. Thus, the data assets may not be available in meaningful volumes or readily accessible in small projects.

Further research with project and organizational actors is needed to expand on the types of digital assets and further classify the data. An interesting extension would be to add the attributes relevant to each digital asset to the classification model. Moreover, determining a strategy for widening the selection of journal used and still providing a meaningful context would be interesting. Alternatively, other qualitative methods such as case studies could also be considered for the research. Finally, the rapid move to remote working driven by the COVID-19 pandemic offers an interesting avenue to research the impact of digital communications on projects.

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