Data-Driven Project Management (DDPM) in the Construction Industry: An Exploratory Study

MOT2910: MASTER THESIS PROJECT

by Yildiray Ocalan
4928393

TU Delft

Ballast Nedam

Data-Driven Project Management (DDPM) in the Construction Industry: An Exploratory Study

Master thesis submitted to Delft University of Technology

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in Management of Technology

Faculty of Technology, Policy and Management

by

Yildiray Ocalan

Student number: 4928393

To be defended in public on July 15th, 2020

Graduation committee

First Supervisor : Dr. R. M. (Robert) Verburg, Economics of Technology &Innovation

Second Supervisor : Dr. P. E. (Pieter) Vermaas, Safety and Security Science

External Supervisor : Serkan Sen, Ballast-Nedam, Head of BIM

Acknowledgements

This thesis brings the challenging yet fructiferous Masters's degree in Management of Technology (MOT) to a close. These past two years recorded on the books as an important experience for me. It could not have been possible without the warm support and assistance from many people. Accordingly, I would like to express my sincere gratitude to everyone who has involved and supported me during the thesis research.

First, I would like to thank my graduation committee members at the Faculty of TPM who have provided me enlightening guidance during this special Corona time. In this regard, I would like to acknowledge my first supervisor and chairperson *Robert Verburg*. Special gratitude goes to him for supporting me with his constructive attitude and for his constant feedback throughout the thesis research. I would also like to thank *Pieter Vermaas* for taking part in the committee as my second supervisor and shaping the research strategy earlier for this thesis.

Sincere thanks to *Serkan Sen* for giving me the opportunity to conduct this thesis at Ballast Nedam and providing pathfinder guidance with his precious ideas. Next, I would like to thank research participants who have spared their time out of their agenda and answered my interview questions. It could not have been possible to obtain rich ideas without their participation in the study.

I would like to thank my friends and family for believing in me and giving moral support and inspiration. It was really valuable for me to know that I can count them.

Yildiray Ocalan

Delft, July 2020

Abstract

With the increasing amounts of data generated from various sources, companies are now aware of the data-driven applications more than ever. In the built environment, building or infrastructural projects are handed over as end-product and these projects are complex. Thus, this data disturbance requires multiple ways of project management practices. The study aims to explore the current state and future uses of data-driven technologies in the construction domain by identifying different project components from the project management stance. The proposed research includes a desk research for data-driven activities in the construction industry and a single case-study methodology which is supported by interviews and a focus group discussion. The study results reveal the importance of each project component on transforming data into information and standards in order to fully implement the technology for different project purposes. Therefore, the research contributes to developing a body of knowledge on data-driven construction management methods by identifying the status quo and serves a starting point for construction managers and researchers regarding data-driven approach.

Contents

List of Figures

List of Tables

1

Introduction

With the rapid growth of advanced technologies, the world is now abounding with data that pushes companies to manage data in petabytes (Bilal et al., 2016). Facebook has more than 10 million photos upload hourly, and Google processes around 24 petabytes daily (Viktor & Cukier, 2013). A huge amount of data is generated from different kinds of sources, consequently, many industries have realized its capabilities to find a way to help them solving common problems and turning operations into a better way (Ismail, Bandi, & Maaz, 2018). Data-driven applications within the industries have a broad range such as fraud detection, flight schedule, customizing medication, and predicting consumer patterns (Loyola, 2018).

Alike other sectors, the rise of data in the construction industry is in a considerable amount. Data-driven revolution is promoted by different sources including drawing software, BIM[1], cloud applications, data analytics, and hand-held technologies (Maskuriy, Selamat, Maresova, Krejcar, & Olalekan, 2019). This data is generated from various technologies and equipment like 3D scanner, virtual reality, simulations, automation, sensors and robots, and prefabrication. As such technologies are implemented in the built environment, the usage of them brings new ways of project management approaches. This means projects and the management mechanism are required to be adapted (Levitt, 2011; Whyte, Stasis, & Lindkvist, 2016)

However, within the construction domain, the amount and the frequency of data in and outflows are not similar compared to other industries, thus most of the practices have been experimentally used for scientific purposes (Loyola, 2018). Although there are few concrete illustrations of data-driven applications in the building sector, influential papers predict its future potential (Bilal et al., 2016). The data used for decision-making and prediction purposes refer to historical data. Yet, the built environment is limited by the nature of the projects in terms of using historical data. Because each project is unique and has its own requirements. Thus Maskuriy et al., (2019) indicate that the repetition process of projects may be the future of the construction industry in order to use project data.

[1] Building Information Modeling

1.1 Research Background

The data or big data, in general, refers to the generation of a huge amount of information. According to Laney, data in the 3Vs model should carry high *velocity*, *volume*, and *variety* properties to be classified as big data (2001). The high volume explains with the generation and the collection of big sets of data, the data portion gets huge. High velocity indicates the time-dependent behavior of data which is progressive. Lastly, variety gathers the distinctive sources of data, as well as data types, e.g. structured or unstructured (Chen, Mao, & Liu, 2014).

Several authors have expanded this definition by adding more Vs, namely: veracity, virtual, value, validity, and venue. For example, big data can be categorized into five dimensions by adding two dimensions (Jin, Wah, Cheng, & Wang, 2015). Authors mentioned veracity, as the uncertainties in data sets and value, as adding extra benefits with complementary trends or enablers in the technology including the Internet of Things, cloud computing, and IT platforms (Jin et al., 2015). Another categorization of big data can be made by the types of data, which might be structured, semi-structured and unstructured forms (Farghaly, Abanda, Vidalakis, & Wood, 2017). It defines the degree of additional process to transform data sets into more apprehensible formats. This categorization is observed as unstructured forms in the built environment where data comes from various sources including drawings, documents, procedures, and material requirements.

Furthermore, project data is mostly created by digital sources and guides to the project delivery. In the built environment, the amount of the sources are excessive, the data generation is of high speed due to the dynamic feature of construction, and there are different types of sources. Thus, the three components of big data are present. Yet, data come in unprocessed and unstructured (Farghaly et al., 2017) forms. In order to transform data into information to interpret meanings, data-driven tools and methods are being used. Therefore, data follow a journey through information, and this generation of information is generally dealt with asset management aspect since information during the whole lifecycle of a project can be stored and used again later. Thus, the information generated and articulated in a particular work is now becoming project deliverable with the presence of big data (Whyte et al., 2016).

Because the construction industry mainly operates to deliver (building or infrastructure) projects as the main output, while the existence of this emerging disturbance cannot be thought without investigating project management practices. In projects, data can be obtained from different sources in different formats, yet the standards to apply them into project-based organizations are also determinant. Hence, standards are crucial (Delisle, 2019) when setting the rules, forming different disciplines, and controlling (Hodgson & Cicmil, 2007). As PMI[2] explains, a project ‘’is a temporary endeavor undertaken to create a unique product, service, or result’’ (2017, p. 4). Project management is, then, can be defined as the embodiment of knowledge and skills, tools, techniques, and activities to fulfill the project deliverables. Thereby, information can be meaningful by analyzing data sets with data-driven tools to achieve project management success.

[2] Project Management Institute

Some of the advantages of data-driven technologies in social science literature can be valuable for construction professionals as well. The data-driven approach can provide competitive advantage (Barton & Court, 2012; Mcafee & Brynjolfsson, 2012), a differentiation for organizations (LaValle, Lesser, Shockley, Hopkins, & Kruschwitz, 2011) and insightful predictions (Boyd & Crawford, 2011) for future improvements. The link for the building domain between data tools is presented by Farghaly et al. through GIS[3], IoT, and sensors & RFIDs over the construction sites where they can be classified as data generators (2017). They also proposed a framework in which data transform into information and later knowledge (Farghaly et al., 2017). Bilal et al. mentioned different file formats (to manage design, collaboration, and coordination) in the built environment to show the variety of data generated from different software, including IFC[4], DWG (for drawing), DXF (for file exchange), RVT (for Revit), MPG (video format) and DOC/XLS/PPT (Microsoft format) (2016). More specifically, HR database, access and security logs for predictive analysis, data tags on the in-site element groups (walls or windows) to track progress, work-order logs from operators to manage the site by using text mining, and building load forecasting by ANNs[5] can be listed as initial uses of big data within the industry (Burak Gunay, Shen, & Newsham, 2019).

As a result, the data disturbance is present for the built environment. Different data sources provide different file formats. These sources are being used for specific project purposes, consequently, the management of the data-driven approach means a great deal for construction professionals. Furthermore, in this particular industry, companies deliver projects as the main output, the effects and the applications of data-driven approach should be considered within the project management scope.

1.2 Research Gap and Research Objectives

As introduced above, the disturbance of digital transformation and data-driven technologies are shaping the way companies managing their projects. Of course, the transformation is also there – even though relatively slow - for the built environment. Numerous research has been conducted which brought different themes into the table, yet it is somehow scattered due to the dynamic nature of both emerging technologies and projects themselves.

As data increases in volume, velocity, and variety, the organizations realized the need for control. In the built environment management and control of processes are done by project management practices. For instance, (Whyte et al., 2016) presented the change management perspective in order to adapt renewed requirements coming with data era. As construction projects deal with significant volume and variety of information, this information is also considered a project deliverable similar to some parts of buildings. These information requirements may include project definition, the role of the stakeholders, communication channel, and the project scope. For this reason, information is treated as an asset and in the literature, information delivery is commonly linked to the management of projects.

[3] Geographical Information System
[4] Industry Foundation Class – common file format
[5] Artificical Neural Networks

This thesis, which is supported by a literature review, indicates that there is not only exhaustive research done on data-driven applications but also project management in the construction domain. Yet, it is surprising that a little amount of literature existed which gathered data-driven techniques and project management in the construction domain. What is more, the papers published under project management, focused on diversified features of projects (e.g., performance management, value management, change management) which further requires an integrated way of a scientific approach to address this need of union. Thereafter, the current state of the literature begs to combine practical data-powered applications in the construction industry and how they can be an opportunity to manage projects successfully, consequently, the research exclusively aims to fill the research gap.

For this reason, this thesis firstly aims to understand project nature. Later, it targets to identify project management purposes by exploring data-driven applications. The research narrative is designed under a framework (Figure 1) which was outlined by PMI. According to PMI, there are five phases of projects described in the PMBOK® Guide[6] (2016). It guides to project management steps and provides a roadmap for the lifecycle of projects. Therefore, the guide will be used as a baseline and the research activities will be scoped down to execution and, monitoring & controlling phases and carried out accordingly. Herewith, the study will aim to explore the current state and future of data-driven technologies in the built environment by following the project components and their relation to management.

Figure 1: Project Management Processes (PMBOK® Guide), PMI (2016)

In conclusion, the relevance of this thesis study is two-fold: The first one is *to understand the current state of data-driven applications* and later is *to demonstrate the gains of data-powered systems for the project management practices in the construction industry by linking with project nature*. The hidden value will be revealed if and only if data is utilized to obtain information to guide different processes in projects. Companies and researchers need to understand the value of transforming large amounts of fragmented and high-speed data into concrete insights (Gandomi & Haider, 2015).

[6] Project Management Body of Knowledge – guide for project phases

1.3 Research Question(s)

To the best of our knowledge, the management of projects and project nature in data-driven context have not been investigated closely. Given the potential of data tools to improve project performance, team communication, and information delivery, it is substantial to comprehend how companies manage projects and explore how project components can provide benefits with data. Based on the above, it has been set out to address the following research question:

- ***Main RQ: How can data-driven technologies enable construction project management practices?***

To help answer the main research question, the listed sub-questions can be formulized to explore data-driven methods for project management purposes. In order to assist the main research question, and in line with the objectives of the thesis, it is aimed to understand the status quo of the data-driven approach for different project purposes. This is targeted by the following sub-research research questions:

- ***Sub-RQ1: What are the current data-driven project management trends and applications in the built environment?***

As far as the second sub-objective concern, it is aimed to understand the nature of projects and how different project components are related to each other and the project management context. The technology aspect (data-driven approach in this thesis) is also inclusively targeted. Thus, the second and third sub-research questions are formed:

- ***Sub-RQ2: What are the components of projects and their relation to project management practices?***

- ***Sub-RQ3: How are the project components important while adopting data-driven methods to manage projects?***

1.4 Thesis Structure

The thesis is divided into three main sections, namely, *description, data collection,* and *results.* In these sections, seven chapters are formulated. Thus, the outline of the research (Figure 2) is as follows:

- Chapter 1 introduces the research topics along with the objectives and research questions.
- Chapter 2 provides the relevant theoretical orientation and background information to create a body of understanding of the problem and lists project and management factors on the data-related application in the built environment. Besides, this chapter also includes the theoretical framework which will be used as a baseline in the research.
- Chapter 3 outlines the research design, including the research method and data collection techniques to achieve the research aims.
- Chapter 4 describes the emerging data-driven trends and project management modules.
- Chapter 5 outlines the semi-structured interview settings and results where 12 people participated in the process.

- Chapter 6 aims to validate the findings from interviews by the focus group method.
- Chapter 7, the discussion and conclusion chapter, presents the results of the study and concludes by providing answers to the research questions, along with the future research avenues and limitations.

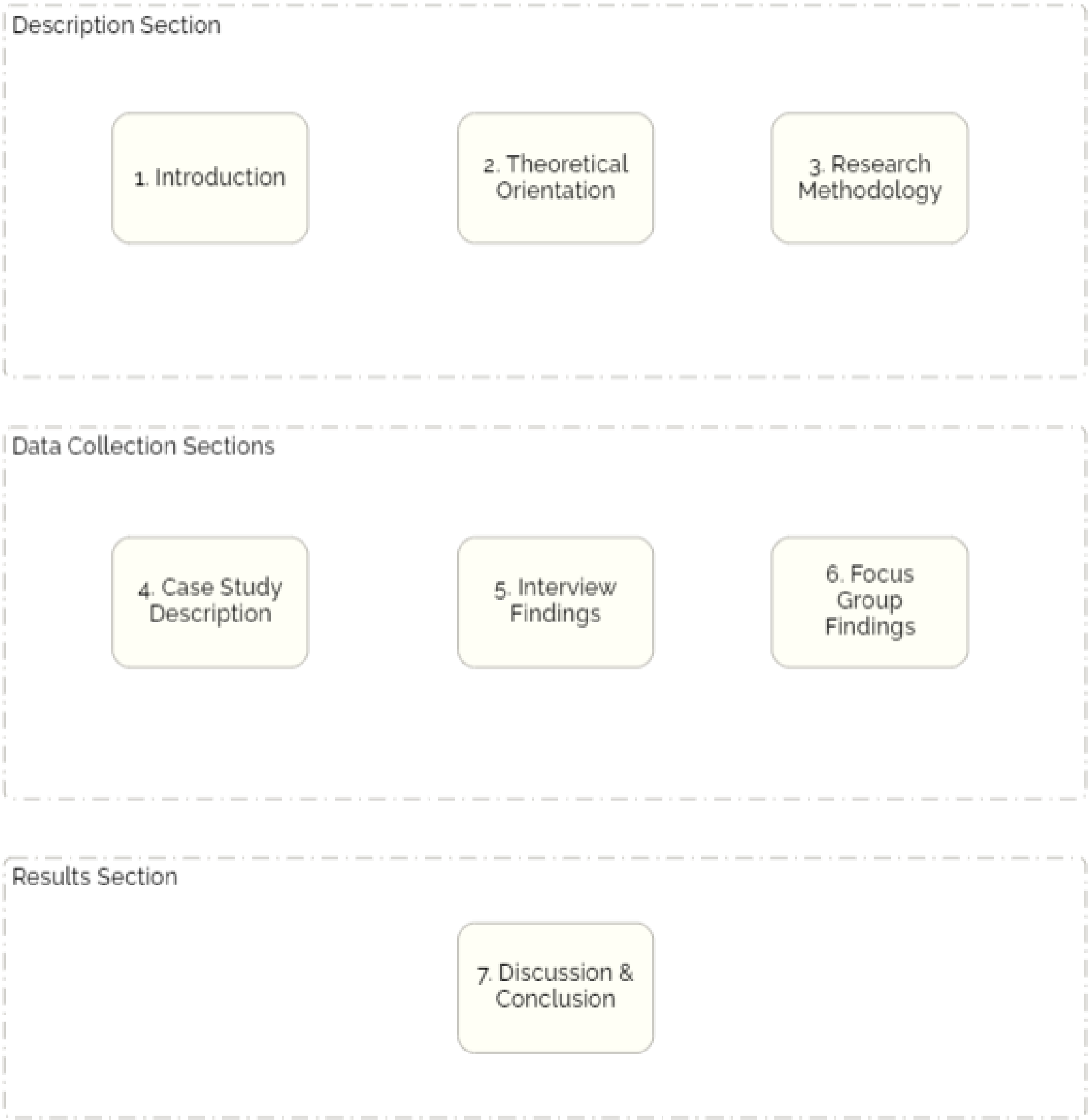


Figure 2: Thesis Structure

2

Literature Review

This chapter presents a literature review in order to identify project nature and how data-driven technologies influence each project component and the management of those components. Thus, while it presents a baseline, it also seeks to answer the following research question:

> ***Sub-RQ2: What are the components of projects and their relation to project management practices?***

First, theoretical orientation provides a framework on project components by treating projects as temporary organizations. For this reason, four different kinds of project components are presented. Secondly, it discovers the current literature of project management by linking it to the framework. Identified project management literature is outlined as value management and time, project teams and governance, project performance, and project phases. Additionally, as for the data-powered applications, the fourth component of the framework, the transition, is used. A general overview of what is a project and to which components they depend on are provided. This is followed by the technological description of the data-driven approach and implementation strategy.

After reviewing the current literature on the data-driven project management applications in the built environment, it revealed that there is a gap in the literature regarding the integration of data-driven technologies into the project management settings. The project part is underrecognized with the data related approach. From the review, it is found that different emerging methods and algorithms are used to meet various project purposes or they are still improving. However, there is a need for aggregation of the findings from hetero-research areas into the project management. This may help to grasp a better understanding of the project components and how the data-driven technologies influence projects, consequently, the management of diverse project applications.

2.1 Projects as Temporary Organizations

Project management has evolved from a practitioner perspective to an academic perspective since the 1990s where scholars had widely studied the theoretical foundation of project management. In this respect, Sydow & Braun, compared two different approaches systematically, namely the work of *Lundin & Söderholm (1995)* and *Turner & Müller (2003)* to point the similarities and differences (2018). The framework of Turner and Müller gathers organizational theory with project management research. Whereas, Lundin and Söderholm investigate the project from a universal point of view by including the major components of temporary organizations.

Furthermore, aiming at a coherent theory of frame for project settings, the seminal work of Lundin and Söderholm on organizational project management defines projects as temporary organizations by establishing a theoretical baseline, the 4-T Framework. The framework (see Figure 3) stands for time, team, task, and transition aspects to better explain the components of projects or temporary organizations. Thus, the 4-T framework will be used to analyze the literature found that is relevant to project management practices. Moreover, the fourth component, transition, will address the technological perspectives which are investigated as the data-driven approach in the thesis. Thus, the transition component of the project is aimed to link the gap between project management practices and data-driven technologies.

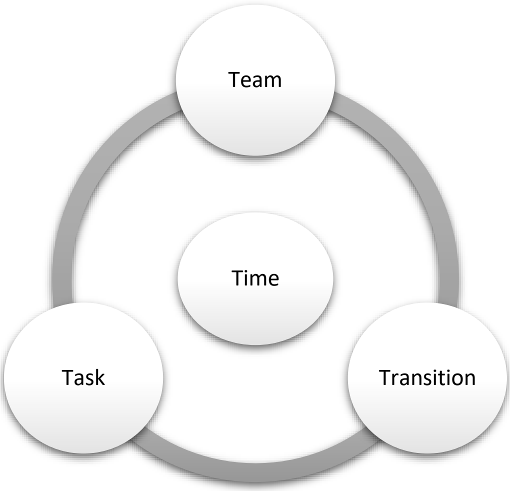


Figure 3: 4-T Framework, Lundin & Söderholm (1995).

Before explaining the theoretical framework, the terminology will be introduced. The framework is used to understand the project settings. According to the framework, there are four different project components, namely, time, team, task, and transition. However, for the sake of this thesis, the term *''component''* and *''aspect''* are chosen to be used interchangeably. It is decided in this way to avoid the repetitive usage of one word. Besides, it is decided not only to show what projects are consist of but also the perspective of different components. In short, project nature will be analyzed by segmenting four project aspects.

In temporary organizations, *time* is one of the most important factors in projects. Specifically, the differentiating point of projects from permanent organizations is the termination mechanism which is *ex-ante* and embedded (Lundin & Söderholm, 1995). On the other hand, being bounded by time brings some limitations not only for the setup of projects but also for projects that are built-in the interplay of various organizations and alliances and the postponed projects that cannot be terminated as planned (Müller-Seitz & Sydow, 2011).

Projects or temporary organizations usually depend on *team* formation and structures where a group of people collectively work. In the construction domain, team settings are of high priority and importance, since the division of huge and complex projects are assigned to those group as sub-tasks. Empirical findings on project teams generally focus on teams as the combinations of individual members instead of treating them as organizational entities (Bakker, 2010). Regarding the teams in organizations, a group of individuals with different experiences, expertise, and backgrounds gathers together in order to achieve the project targets.

The objective of why projects are comprised is explained by the *task* aspect (Lundin & Söderholm, 1995) and it concerns the existence of temporary organizations and evaluation of objectives. Tasks in projects are defined, negotiated, and revised between the team members. Since projects break down into a set of sub-tasks, each task is unique and specific to the incumbent organization (Bakker, 2010).

The *transition* component in the framework is explained as the necessary drive to cope with counter-forces which is indigenous to the organizations (Sydow & Braun, 2018). It indicates the pre and post version of situations by making comparisons. The transition can be observed within the temporary organization as well as the permanent organization that projects belong to. In this explorative thesis, the transition component was analyzed by looking at technological migration.

2.2 Understanding the Project Components

The current literature regarding project management and data-driven approach is categorized and placed under the 4-T Framework. This was done in order to give a structured overview of the existing studies and demonstrate the relevance to the research objective. Hence, the time aspect included value management and cost/time relation; team aspect covered project teams and project governance; task aspect gathered project performance and project phases; transition referred to the technology and implementation.

2.2.1 Value Management and Time

The time component of the framework describes the temporal perspectives of projects where interrelation with the cost and measurement of outcomes exist. This refers to the duration of the projects as well as the characteristic outcome of time – values and benefits. In this context, value creation and value management were widely researched in the examined sources.

Project management literature has scrutinized the deliverables by evaluating projects on time, cost (budget), and quality, which refers to the iron triangle (Svejvig & Andersen, 2015). Matinheikki, Artto, Peltokorpi, & Rajala (2016) basically describes the value as the difference between what you get (benefits) and what you give (sacrifices) during the management of projects (2016). In respect to delivering value, Pargar et al. studied the time dimension (speed and efficiency) and evaluation of value, as well as additional dimensions including social and environmental perspectives (2019). Furthermore, the long-term trait of value and effects are commonly being researched recently (Fuentes, Smyth, & Davies, 2019). Although among the project participants short-term values are emphasized mostly with financial outcomes, the authors indicated that the value and creation process have impacts in the long-run as well. They made a distinction between value and benefits system. The former concerns the realizations of both tangible and intangible output, whereas benefits management considers the delivery of tangible facets as benefits (Fuentes et al., 2019). Thus, their categorization of value may contribute to the evaluation values from various perspectives.

Similarly, the mechanism of effective value creation in projects is also a widely studied area. Riis, Hellström, & Wikström, (2019) investigated the governance system of projects specific to the permanent organization that executes multiple projects. They discussed that the creation of value can be promoted with a well-established project governance mechanism. Therefore, values can link different domains in the organization (Riis et al., 2019). In addition, the remark on the linkage between organizational and value aspects was made to clearly identify, create, and obtain value and outcomes.

The value, which is time and context-dependent, has varying components. Thus, most of the studies treat cost and time simultaneously. Earlier instances from the iron triangle, and evidence from Green & Sergeeva (2019) where they named a value management approach called Hard Value Management, have shown cost reduction is also related to the time-boundedness of the projects. Authors have also referenced the contribution of Laursen & Svejvig (2016) where value, benefits, and cost are coupled. After defining values and relationship with cost, the use of values was also investigated. Because the value created can only be useful if it is evaluated well and sustained. In order to use values and classify values failure or success, several methods have been studied in academia. In this line, one of the leading research topics is project success that is associated with the project progress control and performance. Bryde, Unterhitzenberger, & Joby with the Earned Value Analysis (EVA) method investigated the project success factor (2018). They pointed out the quantitative measurement variables cost (budget) and time (schedule). Even though the performance measurement system takes into account these two views, the deficit integration level of cost and time was identified as the weakness during project phases. In response to this challenge Earned Value Analysis gathers the time and cost-related data and outputs as treat them as one criterion. Thereby, it was addressed that the method to measure performance gives a wider outlook of cost overruns, under-spend (Bryde et al., 2018), and project delivery time.

2.2.2 Project Teams and Governance

Construction is a field in which building or infrastructural works are delivered as a final of the projects. These projects gather many stakeholders whose expertise and interest are different. The owners, designers, contractors form the grounds of the actors, then subcontractors, financial officers, attorneys, and public agents include in the process. Hence, project teams are formed by people with different professions, expertise, knowledge, and education but working on the same goal – project success. Teams also include the interactions among people both internal and external to the main organization. Thus, to better understand the team component of temporary organizations project teams and governance were analyzed.

Team concept and the workplace usually mentioned with the interactions among members and the project performance in the literature. By pointing out the complexity of projects, Bjorvatn & Wald argued team-level capabilities as the driving force of team performance (2018). Additionally, the formation of teams is included the objectives of all stakeholders during the whole lifecycle of the projects. Similar reasoning is addressed by Pargar et al. regarding project alliances (2019). Moreover, new ways of project delivery methods are emerging to meet the particular needs of a client. Mesa, Molenaar, & Alarcón, (2019) presented a comparative outlook of integrated project delivery (IPD) and lean project delivery (LPD) for the construction industry. Each type of project delivery brings a different solution to businesses, yet the information and value generated through the interaction of stakeholders are strongly related to the level and capability of exchange among the participants. Therefore, the IPD approach is stemmed from the idea of collaboration and addressed the importance of project teams.

Similarly, when explaining project teams and people interaction, the BIM notion is also commonly researched and it is getting increasing attention in the Project Management research in the construction domain (Papadonikolaki, van Oel, & Kagioglou, 2019). BIM can be described as the emergence of various digital platforms as well as the digital transition of the traditional habits, therefore this collaborative platform gathers involved stakeholders in the project to work in a synchronized way to design, share, annotate, edit, and comment on the task at hand. It is also an integrated assistant tool for project management while contributing to procurement, construction, (pre)fabrication, and facilities management (Bryde, Broquetas, & Volm, 2013). The literature on BIM, with its current state, focuses on the collaboration among the involving actors, yet the way to maintain this collaboration is still problematic. Oraee, Hosseini, Papadonikolaki, Palliyaguru, & Arashpour, (2017) studied the BIM-based collaboration from Project Management stance by specifically focusing several sub-perspectives, namely: integration management, communication management, and stakeholder management. In the built environment, projects break down to structures in which teams are working together and when it is well-communicated the degree of collaboration can contribute to the project progresses. Thereby, it is a new component of project team interaction in the construction domain.

Alongside the project teams, the governance mechanism of temporary organizations were found to be the frequent trait of teams supported by the literature. As Müller, Turner, Andersen, Shao, & Kvalnes (2016) describe, project governance refers to the interactions among the project members which can be influential on stakeholder engagement and the trust built in the project environment (Derakhshan, Turner, & Mancini, 2019). Another team-oriented finding closely related to the task component was touched upon meeting customers' needs and business objectives. Furthermore, the success criteria were also combined with the stakeholder management to address the project performance levels.

In a similar manner, Ismail, Bandi, & Maaz, (2018) drawn insights for project governance to understand different aspects of project management processes. In order to explain different governance mechanisms a grouping, in which (management) concepts were combined, was made (Ismail et al., 2018): Project management, safety management, decision making, and resource management. The project management aspect involves progress monitoring via IoT devices, improvement in cost efficiency, and delays which ensures better project productivity and used by project members. Safety management consisted of the site and worker related tracking systems that relate to team monitoring. The decision-making category gathers how to make prompt and informed decisions in the built environment. Lastly, the resource management dimension combines the utilization of resource efficiency, including teams, through resource tracking. As seen, even though management approaches points out the other component of projects as well, different views of governance were studied concerning project teams.

2.2.3 Project Performance and Project Phases

The task component of projects is often connected with the project performance or project success and the phases of projects. Since delivering the project is the main task of temporary organizations, numbers of sub-tasks can be branched out. Traditional project management investigates projects as an individual notion (Sydow & Braun, 2018). Although the approach identifies the uncertainty elements in projects, it has shortcomings about complete capturing of the dynamic nature of projects. In this way, projects are defined by a specific task and treated as single entities. Thus, they are designed to be executed uniquely.

The routes of the traditional project management have stemmed from two main domains (Söderlund, 2004), namely: engineering and social sciences. The former area mainly focuses on methods and techniques of planning, and the latter encapsulates the behavioral and organizational views of project management. While the nature of projects in the traditional approach is static and the project itself is in a well-defined boundary, the relationship with its environment is highly dynamic. The challenges of the relationship are addressed in a study (Kreiner, 1995) that the problem is about the co-evolving of the project's scope. After it is initially defined and it may evolve due to the changes and needs in the environment. Therefore, the issue happens when the project is created as a set of tasks when the needs and conditions deviate from the main goal which was prepared and planned in advance. As two view complements each other, it means that a project cannot be managed without defining certain tasks and sub-tasks. Hence, the nature of the (construction) projects is prone to be dynamic where unexpected issues may arise. On the other hand, it is not that easy to apply two views as a combination, since there should be a guide or set of rules to follow or benchmark for start.

In order to address the task and dynamic nature of construction projects, criteria regarding project performance were analyzed in the literature. Derakhshan et al. (2019) address the distinction between project success and project management success in their paper. The former concerns the meeting business objectives and strategic goals and the latter explains the triple constraints (time, cost, and quality). Yet, for the sake of literature analysis, the terms success and performance have treated interchangeably. Thus, the findings from the papers usually mentioned the similar metrics on project management: time, cost and quality (Bjorvatn & Wald, 2018; Derakhshan et al., 2019; Lu, Cai, Wei, Song, & Wu, 2019; Pargar et al., 2019).

Besides, performance measurement criteria such as team satisfaction, meeting customer requirements, and market share were addressed in the current literature (Lu et al., 2019).

Performance in projects can be measured and monitored differently. Kim et al. (2018) presented the main standards published by the Project Management Institute (PMI) and the Global Alliance for Project Performance Standards (GAPPS) and methods like the key performance indicators (KPIs), benchmarking and metrics (BM&M), and earned value management system (EVMS) in order to understand the monitoring mechanism. Thus, these metrics were found to be initial standards that can be used by the stakeholders to monitor the project performance and obtain useful information. Yet, the authors also identified that because there is not enough combined data, evaluating the project performance with the progress information may be reasonable (Kim et al., 2018). Similarly, Bilal et al., (2019) had outlined that the performance measurements in the built environment can be done through profitability evaluation. Progress in projects is usually defined as the percentage of work finished regarding budget (Kim et al., 2018). Thus, it is a vital management duty for companies to track the project progress, continuous if possible, during the whole lifecycle of construction in which the initial step is generally to define the proper profit margins (Bilal et al., 2019). Svejvig & Andersen (2015) also discussed project performance by comparing Rethinking Project Management (RPM) approach with classical project management systems. Classical practices classify the project as a tool where success is performance-dependent and treat project management as a set of tools and techniques. Whereas, projects in RPM, are defined as temporary organizations that are evaluated based on efficiency, effectiveness, and innovation and project management is a holistic discipline. Thereby, regarding tasks in projects, it was addressed that performance measurement can be carried out in different ways and it is important to realize business goals and track the changes during the project phases.

Another perspective of project tasks concerns the project phases where each step brings different requirements. There are established guidelines to be followed during the project lifecycle. For this reason, Takagi & Varajão (2019) presented a discussion around the existing project management methodologies. The study explains the major methodologies and guides for project management. PMBOK, as a guide of best practices, gathers processes such as planning, and execution and knowledge areas including stakeholders, communication, and quality. The PRINCE[7] methodology is a project management approach that encapsulates themes, principles, processes, and project environments. The third approach, P-M squared (PM^2), is a standardized management concept by the European Commission and promotes the communication of the project team. It integrates similar processes like PMBOK, yet the monitoring & controlling phase is referred to as cross-project-wide activities. Similarly, construction management referred to by Maskuriy et al. (2019) as an approach to execute projects successfully during the whole lifecycle. They mentioned the RIBA Plan[8] of Works for project phases which applies the following pattern: Need for the project, conceptual design, and planning, actual design, procurement, construction, operation, and maintenance.

[7] PRojects IN Controlled Environments
[8] A plan by Royal Institute of British Architecture which outlines different project phases

Moreover, the link between project phases and values obtained was studied in the literature. Findings from the paper on project benefits management outlined that targets like costs and project goals are defined in order to achieve project completion (Zwikael, Chih, & Meredith, 2018). Two types of benefits were investigated in the project phase context: targets prior to project commencement and targets that shape during the project execution. Again, project performance was connected to the task component, by addressing the need for a well-established performance measurement system. Thus, when it comes to evaluate the outcome or classify a phenomenon, some standards, or at least a contribution to the results is desired to be observed. In this line, Green & Sergeeva explained by looking at the values and how they are created and/or retained in and during the process of projects (2019).

Herewith, while analyzing the project settings it is important to take into account project phases. Even though all phases were not explicitly named or mentioned by the authors, the lifecycle of the temporary organizations was framed by some (Maskuriy et al., 2019; Takagi & Varajão, 2019; Zwikael et al., 2018) on a phase-based mechanism. What is more, the developed guides and methodologies are in use, yet the authors revealed that they do not explicitly address success management. Since management of success, comprises the management of cost, schedule, risk, scope, quality, etc., the performance aspect revealed to be related to project phases.

2.2.4 Data-Driven Technologies and Implementation

The last component in the 4-T framework – transition – will be used to explain the gap defined in this thesis study. Thus, the aim is to analyze data-driven approaches as a transition and link them into the project management perspective. Technology and implementation were founded the most used areas which assist to justify the transition aspect. Furthermore, since the data-related project management studies in the built environment are scare, this sub-chapter builds on the knowledge gap explored so far.

Regarding the data phenomena in the construction industry Loyola (2018) discussed the transformative effects of the technology by also addressing the additional needs for further research during the whole lifecycle of projects. The disruptive effects included pre-design, design & development, construction documents, construction, and operations. Next, data-driven applications assisting to project management were found as site analysis, generative design, constructability analysis, performance monitoring, and information communication (Loyola, 2018). Furthermore, like other innovative technologies, Big Data becomes more disruptive with its enablers in the digital era we are experiencing. As introduced before, data carries properties of *velocity*, *volume*, and *variety* (Laney, 2001). Thus, data-driven applications usually follow certain stages of the process. Data is first captured from the source. Captured data is then stored with necessary infrastructures. With the gathered data one can apply big data practices, such as data processing, data analysis, and result monitoring (Farghaly et al., 2017). The method to employe those steps is called data analytics.

In order to obtain insights for project management by data analytics, Han & Golparvar-Fard (2017) studied the use of visual technologies like digital cameras in different field applications. The interactions between different project participants were addressed including field personnel, project engineers, and subcontractors. Thus, this study can exemplify technology as a transition that should be incorporated among various stakeholders. Analogous to Han & Golparvar-Fard, (2017), the data technologies to overcome delays and cost overruns during the project phases, were studied by de Andrade, Martens, & Vanhoucke (2019) to present a comparison of predictive methods on value creation and evaluation. Also, the forecasting accuracy of the predictive technologies is found related to the time (and cost) component(s) of projects.

Similarly, data analytics for improving building performance is encapsulated as the data embodied construction systems, IT infrastructure, computer-aided maintenance solutions, and authentication systems to strengthen construction projects (Burak Gunay et al., 2019). Through the analysis, several sources of data that are generated by sensing devices with IoT connections identified. These sources are the raw material for data analytics to deduct data-driven decisions and included access registries to track in/outs, security cameras for counting people, sensors to monitor temperature, CO_2 and airflow, lighting and occupancy sensors, Wi-Fi device counts from IT, and HR sources for employee performance and satisfaction. The purpose of use for the identified sources was mentioned as predictive and preventive maintenance. In addition, data-driven techniques, which can help both professionals and academicians, were contained ANNs, machine learning, regression trees, and text analytics. Similarly, Bilal et al. explained BDA[9] as the tools and techniques to make use of data, such as machine learning, data & text mining and regression, whereas BDE[10] is a supportive aspect that provides infrastructure, including data storage with databases and file systems (2019). Yet, the need for further research to examine in-depth how these techniques can contribute to analyzing data sets in the construction domain was recommended to fill the gaps in the applications.

Similar yet another scientific field, computer vision, was also examined widely in data-driven boundaries within the construction management literature. It is defined as the capture, analysis of digital images, and extraction of multi-dimensional real-world data to create knowledge to inform the decision-making process (Zhong et al., 2019). Although data generation and processing with computer vision are currently using for safety monitoring, detecting structural and architectural defects and productivity analysis, several challenges were presented such as data privacy while data sharing, lack of a proper database for larger datasets, technical issues while detecting an on-site object and lack of expertise on neural network analysis.

Therefore, there is a huge number of complementary technologies of data-driven approach in the literature focusing on the technical and scientific aspects. Deep learning as a sub-category of Artificial Intelligence to generate unique designs (As, Pal, & Basu, 2018), contractor selection using fuzzy logic (Taylan, Kabli, Porcel, & Herrera-Viedma, 2018) and construction site accident analysis through text mining, digital twins with machine learning (Woodhead, Stephenson, & Morrey, 2018), and natural language processing (Zhang, Fleyeh, Wang, & Lu, 2019) can be some examples. Yet, how to implement these data-driven tools and techniques into project management is hardly mentioned in the construction research.

[9] Big Data Analytics
[10] Big Data Engineering

The construction industry where the businesses are based on large projects is generally vulnerable to disruption. Completion of the complex set of projects usually falls behind the scheduled time while excessing budget up to 80 percent and the productivity in the built environment had declined since the 1990s which in turn had caused financial returns to be unsteady and low (Agarwal, Chandrasekaran, & Sridhar, 2018). The McKinsey Global Institute had outlined that the current digital transformation may be a solution for fixing the basics as a start, even though the construction industry had been slow for the adoption of innovative technologies (Agarwal et al., 2018). In this line, the implementation and the adoption process of the technology are discussed widely in the literature.

The rise of the inter-related digital technologies like IoT, Artificial Intelligence (AI), and smart production constitutes a spillover effect (Maskuriy et al., 2019) with the presence of the fourth industrial revolution. Accordingly, the concept of *Construction 4.0* which covers not only the construction phase but also the whole lifecycle from design until operation and maintenance to scope their review on digital transformation. By unfolding the status quo for the digital construction, it was suggested that the ICT system is crucial to the construction industry, consequently, the value of the findings had pointed out that the professionals should be more in contact with ICT experts and researchers to boost the digitization of the work processes. In the literature, the current digital era was mapped to explain the adoption of emerging technologies as well (Woodhead et al., 2018) in the construction industry. For example, with the increased numbers of sensors available, there will be huge amounts of data flow which can improve decision making while providing data as raw material. These networks of sensors, which are mostly wireless, form the IoT ecosystem. Thus, the studies had argued that the companies who understand the need for a planned IoT ecosystem, can harvest long-term benefits. In addition, the technology systems were mentioned, where the elements of integrated software and hardware, connectivity, and information flow can be used to inform the decision-making process.

In the built environment the execution phase is followed according to design. Thus, design-based processes are of high priority not only for the site team but also for the management. Ahmed, Aziz, Tezel, & Riaz, (2018) explained the connection of the design-related parameters and management-related process (scheduling, planning, and monitoring) into an integrated platform. The drivers and barriers were compared to the transition regarding the *standardization* of data technology. The most important influencing factors for drivers were founded as process improvement, cost reduction, KPIs, and decision support tools by linking them into the design, construction, and procurement phases. However, challenges included the fragmented nature of the built environment, IT system development, skill requirements, and fluctuating business goals. In the same line, Sirisomboonsuk, Gu, Cao, & Burns, (2018) proposed success factors for IT implementation and project performance. Of those factors project duration, documentation of responsibilities, the existence of benefit management systems, effective learning mechanisms from experiences, and portfolio existence can be listed as evidence to transition aspect. Consequently, technology implementation goes hand-to-hand with project implementation and thus falls into the transition component of the projects.

Likewise, Ahmed, Tezel, Aziz, & Sibley (2017) investigated the current situation, drivers, opportunities, and barriers of data-driven technologies. Another study had addressed a similar direction for implementation in construction projects by focusing on resource management which was defined as any contributory factor to deliver the project needs (Kusimo et al., 2019), and seven notable elements revealed, of the elements, the poor structure of data management systems and data being in silos were noted the most significant ones.

Notwithstanding the benefits of data to manage projects are partially perceived, the empirical research efforts on the data-driven approach within the construction domain are scarce, consequently, this literature review draws attention by providing a theoretical foundation on projects. The digital transformation in the project management context for the built environment is growing and it is strongly related to the amount of data generated from various sources that are mostly connected. One should consider the importance of data-driven and comprehend how to process to make data-driven decisions.

2.3 Synthesis of the Literature Review

This chapter provided a foundation in order to understand project settings and relevant management concepts by linking them with knowledge of data-driven technologies. Firstly, to explain project components, the work of Lundin and Söderholm on organizational project management was introduced. This theoretical baseline made it possible to identify project aspects. Secondly, the project management literature was grouped according to the 4-T Framework. A decision was made while grouping the current research. In this way, data-driven technologies categorized as the transition aspect of the framework. Additionally, time aspect addressed value management and time relation; team aspect gathered project teams and project governance; task aspect showed project performance and project phases; transition covered to the technology and implementation.

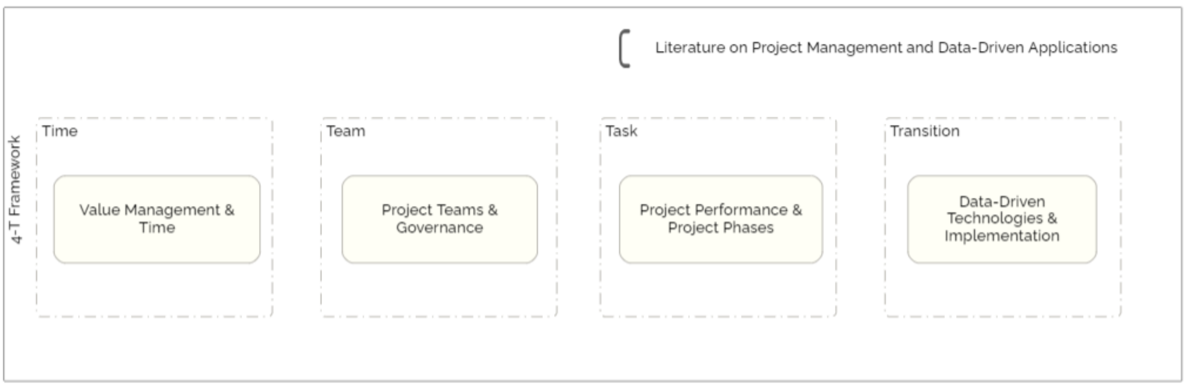


Figure 4: Theoretical Grouping of the Literature

Figure 4 above visualizes the different project components and chosen literature under these categories. This structuring made it easier to realize how projects are formed and the distance of data-powered practices to them, which was already defined as the research gap. Thus, the literature review indicates there are different applications of project management regarding project components, time, team, task. What is more, data-driven technologies are developing and emerging with the existence of huge data generation. Yet, they are still not matured and in the transition phase for projects. Hence, the applications of technology and project management are observed to be divergent. This was exemplified by the implementation barriers including lack of data integration or use, lack of infrastructure, and training level.

Under the time aspect, value management, and the cost-time relation around the iron triangle (time, cost, and quality) mentioned as the main dimensions in value creation (Green & Sergeeva, 2019; Pargar et al., 2019). Cost-time connection identified in most of the sources analyzed. Some described this doubling from value perspectives, whereas others addressed the project performance.

As for teams, Pargar et al. (2019) presented project alliances and Derakhshan et al. (2019) touched upon teams by the project governance mechanism and stakeholders. Similarly, Bjorvatn & Wald (2018) identified team-level capabilities as the metrics of project management performance.

The task component was mainly addressed by project performance and project phases. Most of the sources mentioned project performance as the main drivers of the task aspect. Performance of projects has been researched by quality management (Lu et al., 2019), benefits management (Zwikael et al., 2018), project and IT governance (Sirisomboonsuk et al., 2018) and value management (Green & Sergeeva, 2019; Pargar et al., 2019).

Transition as technology addressed the specific data-driven techniques in the literature chosen on projects. Implementation has explored some drivers and barriers. This may be due to the complexity and maturity level of the data-driven approach as well as the absence or lack of necessity forces against change. Specific to data-related project transition, Loyola (2018) has reviewed big data in building design, Ahmed et al. (2018) identified the drivers and barrier of data mining in construction projects, and Han & Golparvar-Fard (2017) explored the potential of visual data for performance analytics. Thereafter, findings on the comparison of duration management techniques had identified project time forecasting possibilities (de Andrade et al., 2019). Lastly, Sirisomboonsuk et al. (2018) identified project performance with the relationship between project governance and information technology governance.

To conclude, even though components had analyzed separately and mentioned in different frequencies in the literature, this chapter has shown that they are interconnected. Therefore, when exploring project management practices they should be considered together. For this reason, this thesis aims to explore the impact of the project components on data-powered tools and techniques and accordingly discover the status quo of project management practices.

3

Research Methodology

Firstly, in order to carry out scientific research, a clear picture of the research design should be presented in a well-organized manner. The research is mainly designed as explorative according to the nature of the research questions and the aim is exploring and understanding data-driven project management practices in the built environment. Thus, this chapter outlines the road map and methods which will be used to answer the main research question and assisting sub-questions in the below table:

Table 1: Research Questions

Main Research Question
How can data-driven technologies enable construction project management practices?
Sub-research Questions
What are the current data-driven project management trends and applications in the built environment?
What are the components of projects and their relation to project management practices?
How are the project components important while adopting data-driven methods to manage projects?

In the first section the chosen method – case study - will be explained. The second sub-chapter will be dedicated to different data collection techniques to obtain relevant information with varying methods. The third section will present the data analysis and interpretation of the collected information. The last section will clarify the outlook of the research path by formulating a recurrent strategy. Later, data gathering will start with Chapter 4 where the desk-based method employed to have an understanding of project management trends in the construction industry.

3.1 Case Study Design

The setting for the case study is designed as a single and embedded one. The design of the research offers a solid baseline for the subsequent steps, data collection, and data analysis. The case in the thesis will be investigated in order to explore data-driven applications and opportunities within the project management context in the construction industry. The case study is also scoped down the execution and monitoring & controlling stages according to the PMBOK guide.

Furthermore, through observing real-life conditions in the construction sector, the case study method brings a deeper understanding on the table about how temporary projects are employing data-driven tools and techniques by the permanent organizations. To answer the research question, the motive here is to identify people's opinions and experience and grasp the status quo and future direction of data-driven project management applications where there is a gap between project management and data-powered tools and applications. This aim was realized by interviews and a focus group.

The case company in the thesis, *Ballast Nedam* is the main contractor operating both in the Dutch and international construction markets. That is what makes them suitable to observe upon. Additionally, the unique scope of their construction projects like a shopping mall - the Mall of the Netherlands, the biggest one in Europe – and other projects justifies the case as a critical one. Thus, the rationale for a *critical case* (Yin, 2018) selection is met since they realize the importance of information to improve the project management workflows. Consequently, a corporate entity – Ballast Nedam- participates in the research as the main unit of analysis. As the thesis study bounded with a single organization the case study type is determined as a single-case. On the other hand, data collection shifts to the embedded level (Yin, 2018) where a group of professionals from different departments has participated (see figure 5) in the study. More specifically, under a bigger unit of observation embedded units of analysis are present. In this way, it becomes possible to grasp different levels of information from varying experiences and expertise. Thus, the case study focuses on the department building projects under the construction division (see Chapter 4 for details).

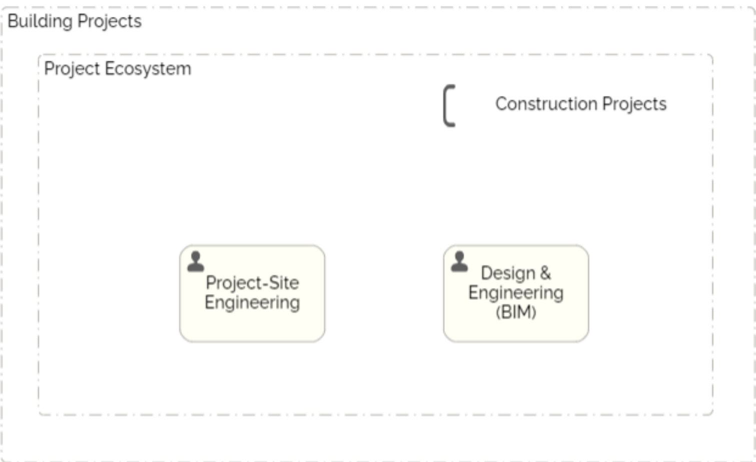


Figure 5: Embedded Case Study Settings

Furthermore, having a theory or basing the study on a main theoretical orientation is also important. Therefore, to prepare for the case and extract better results from it, *literature review* and *desk-based methods* are used to complete the essential methodological steps. The chosen theoretical baseline for the thesis is the 4-T Framework. Besides, there are *interviews* and *focus group* sources included in the study where each method is combined and triangulated to strengthen the findings. Because of the exploratory nature of the research, there has been no proposition or theory testing purpose. Yet, the analysis of the descriptive chapters (Chapter 2 and 4) of the thesis provides a baseline for further exploration by interviews and focus groups. Furthermore, using multiple techniques ensure the *external validity* and *reliability* of the result when judging the quality of the research design (Yin, 2018).

3.2 Data Collection Methods

The data collection framework has been established according to Figure 6 below. Four main steps have been followed. This means that each step had yield findings which then were used as inputs for the subsequent collection method. Therefore, iterative and confirmative data gathering had been conducted. Interim findings from the literature and desk research had provided insights to prepare for the interviews and the focus groups.

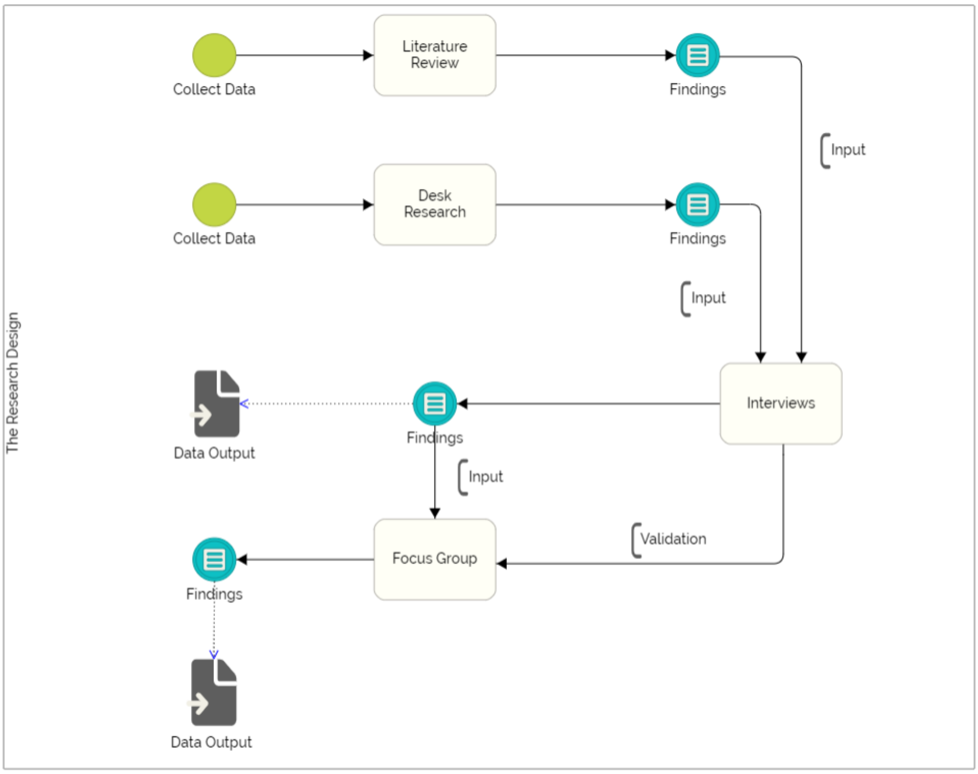


Figure 6: Data Collection Protocol and Triangulation

Organizational documentation and archival records and interviews are decided to be used along with the literature review. As a start, a literature review was carried out. This identified the project settings and their relation with the data-driven applications. Later, desk-based research was conducted. It aimed at describing and identifying the status quo of the project structure and data-powered management systems in the organizational settings. Following this, interviews and a focus group were used to gather personal opinions, motives, and experiences. The next sub-chapters describe the steps followed for each data collection method.

3.2.1 Literature Review

In order to map what is the current state of the research, a literature review was conducted. Firstly, to understand the project components, a framework was introduced. Building on this theoretical baseline the project management literature were grouped accordingly. Thus, the theoretical orientation was aimed at answering the following sub-research question.

- *Sub-RQ2: What are the components of projects and their relation to project management practices?*

A choice was made in the literature review concerning the data-driven technologies. As the chosen framework indicates, the transition component was treated the technological migration, consequently, the review made it possible to connect the data-driven approach with other components of projects.

3.2.2 Desk-based Method

To have an understanding of how data-powered tools and techniques are applied in projects in the construction industry, desk-based research methods are used. The method along with the literature provides a starting point and serves as a guide to continue with subsequent data collection methods. In addition to the theoretical findings this step targets to answer the sub research question below:

- *Sub-RQ 1: What are the current data-driven project management trends and applications in the built environment?*

Data collection is aimed to describe the current state of the data-driven application in the construction domain where projects are the main deliverables. For this reason, the digital trends and standards in the built environment were identified and the case company with relevant background information was introduced. The public database, as well as company servers, were used which was accessible to the researcher during the internship period. Organizational procedures and protocols, project plans, presentations, team sharing documents, and the software were examined. By explaining the context of project phases, and organizational structure; the project structure at Ballast Nedam was described. Data-driven processes, according to usage aim, are grouped in line with the various project needs. As a result, the desk research conducted, aimed to serve a preparation phase for the following data collection techniques.

After gathering information and drawing interim findings from the data collected by secondary sources, the primary data collection technique will be used with two varying settings. These include interviewees from different job titles and professions and a focus group variation with the participation of the higher-level managers.

3.2.3 Interviews with Project Participants

Participants from the chosen observation unit – Ballast Nedam Building Projects- have involved in the data collection process. Information from the respondents was collected about their professional experience, personal beliefs and opinions, and practical use of data-driven project techniques. Thus, the primary data collection for this study is done via interviews in order to help to answer the following sub research questions formulated in the first chapter:

- *Sub-RQ3: How are the project components important while adopting data-driven methods to manage projects?*

Interviews were designed as semi-structured, consequently, rather than obtaining closed-end responses a wide spectrum of issues at hand were collected which is suitably fitted into the explorative nature of the thesis research. Yet, some fixed questions were formed as well and these questions directed to each participant. An interview protocol and information sheet were formed in the light of the data collected and partially analyzed with the previous methods (literature study and desk research). As introduced in Chapter 1, the interview protocol was also shaped around the execution and controlling & monitoring phases of projects in the built environment. This allowed questions and the overall structure of interviews to be consistent with a pre-defined theory. Besides, it helped respondents to picture the project phases in the management context. During the special Corona outbreak, all interviews were planned to be conducted virtually using video conferences.

The first two interviews were held on the same day to explore and test the applicability of the protocol. In this way, it can be called as initial testing as well, since it allowed the researcher to obtain information and make comparisons quickly. The following interviews were also conducted in one-to-one settings and lasted 45 minutes on average. Importantly, interviewees were chosen from the two departments, namely design & engineering and site-engineering. Professionals from these departments were chosen because they are working closely during the execution phases of projects. Thus, gathering participants from two-related groups helped the researchers to ensure the external validity in the study is of high quality.

Participant Description

The population means the whole group of people or events that the researcher finds valuable to examine. Yet, in qualitative studies, it is difficult to investigate the entire population. Therefore, this thesis uses a sample approach while choosing the interview participants that are diverse in expertise and knowledge to represent the entire population. When it is necessary to retrieve specific information or explore a topic, the *purposive sampling* method is used where the researcher targets the groups who can give the desired information (Sekaran & Bougie, 2016). The group can be the only one who posses the information or fits criteria that are defined in the research settings. Even though purposive sampling has constraints regarding the generalizability of findings, it is widely used for exploratory studies.

For this reason, a purposive sampling method is used. The participants are selected according to the project organization chart that was explained in Chapter 4, showing the titles and responsibilities of project teams. The division under the Building Project section is considered. Thus, site engineers, managers, and coordinators of the BIM department and project engineers/designers included (Figure 7) into the interview pool. This selection can be justified with the following. Firstly, site engineers who have hands-on project experience and project engineers and coordinators with a wide spectrum of knowledge on project-related processes are identified. In order to link these aforementioned project positions, the BIM department is selected as the transition because of its high level of integration with data-driven technologies. Additionally, BIM managers and coordinators are included since some numerous data-related tools and techniques fall under their job authority.

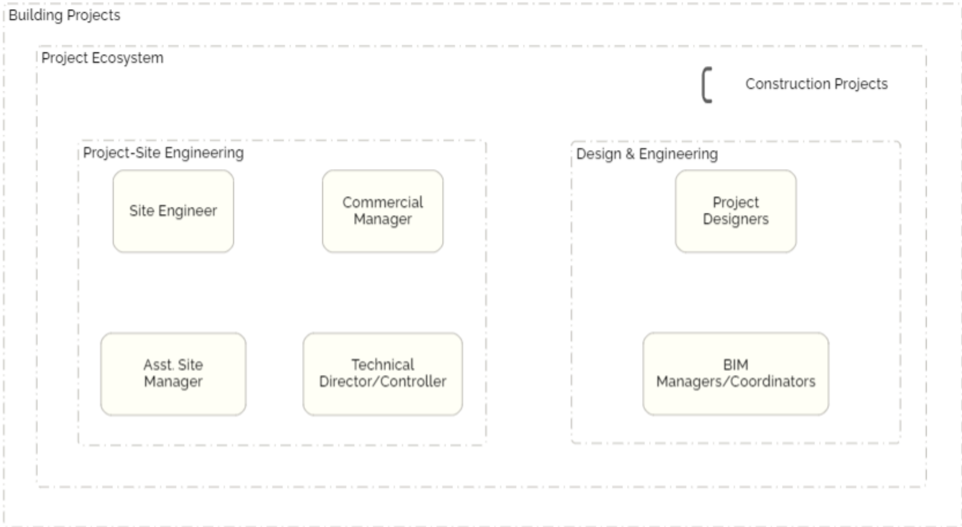


Figure 7: Interview Participant Pool

In this thesis, the main interviewee pool is represented by the design and engineering department. The first participant type gathered BIM manager and coordinator titles and project designers were chosen as interviewees. As explained in Chapter 4, BIM technology does not only concern the design but also the whole lifecycle of the project. It was also explored, within the BIM scope, there exist many data-driven opportunities connecting the project data together. Therefore, manager and coordinator titles are selected to grasp their deep level of knowledge and experience. Project designers included because of their hands-on project experience with data-driven technologies. This also helps in revealing the data-powered project applications that can be distributed among the whole project team. Thus, a purposive selection is made to obtain the most relevant and insightful information, and Table 2 lists the participants with their job titles.

Table 2: Participant List and Titles

Index	Job Title	Department
P1	BIM Manager	Design & Engineering
P2	3D-Modeler, Project Designer	Design & Engineering
P3	BIM Manager - Site	Design & Engineering
P4	BIM Modeler, Project Designer	Design & Engineering
P5	BIM Modeler, Project Designer	Design & Engineering
P6	BIM Coordinator	Design & Engineering
P7	Senior Site Engineer	Project-Site Engineering
P8	BIM Specialist, Digital Construction Lead	(Infrastructural) Design & Engineering
P9	Assistant Site Manager	Project-Site Engineering
P10	Technical Office Director	Project-Site Engineering
P11	Technical Cost Controller	Project-Site Engineering
P12	Commercial Manager	Project-Site Engineering

The second participant type is selected from the project-site engineering department, according to their seniority level as well as their interactions with the BIM-based technologies. They are responsible for the preparation of the design work as well as project planning. This relates to the project management phases identified earlier in the report. Therefore, in order to demonstrate the site perspective of the management of construction projects, participants included managers, engineers, and directors. Similarly, this selection refers to the controlling & monitoring phases in PMBOK guidelines and aimed to explore the algorithmic project management situations in construction sites. In conclusion, while selecting an interview participant the researcher paid utmost attention to balance the diversity on experience as well as relevance with the technology. As pointed out in Table 3, participants are selected for their level of data-driven technology use and on-site involvement.

Table 3: Selection of the Participants

	Interview Participants	
	Project-Site Engineering	*Design & Engineering*
Data-Related Technology	Moderate	High
On-site Involvement	High	Moderate

Next to identifying possible interviewees, an invitation e-mail was sent to explain the research and ask for their participation. Lastly, in total, out of 16 candidates, 12 were responded positively. Given the Corona pandemic constraints, these 12 participants were interviewed via conference calls.

3.2.4 Focus Group

The final data collection technique is a focus group with the participation of the project leads from different sections in Ballast Nedam. Managers are invited to take part in the research based on their experience and knowledge about digital construction management. Inputs are used from the interview findings to form the focus group structure. Even though participants are internal to the company as interviewees, their expertise and international experience were different from the interview group. Furthermore, the focus group is designed to include an open-discussion section regarding the status quo of data-driven tools techniques and possible future benefits in construction project management. Thus, the main motive here is to discuss the interview results and derive conclusions. The collective findings of the interviews and focus group will assist the interpretation of the results and preparation for discussion and conclusion chapters.

Participant Description

Since the research topic is about data-driven project management, the focus group participants were selected regarding their relevance about project management and information aspects. Table 4 lists the managers that were present during the discussion. Similar to interviews, because of the engagement level with data-powered applications, M2 was chosen. Besides, M1 is the responsible manager of the participants in the interview pool. In order to keep the group conversation manageable, the size was limited to two people. Barnet (2002) suggests that a group discussion session can take up to 90 minutes to avoid participants get distracted from the topic. Thus, the focus group meeting in the thesis lasted 58 minutes.

Table 4: Description of the Focus Group Participants

Index	Job Title	Department
M1	Head of Building Engineering	Building Design & Engineering
M2	Head of BIM	Building Design & Engineering

3.3 Data Analysis

Qualitative data gathered from different primary and secondary sources come in forms of words. After data collection, as Miles and Huberman (1994) indicates there are three steps to follow: data reduction, data display, and conclusion drawing.

In qualitative data analysis, the first step is to reduce to data which refers to the selection, coding, and categorization of collected data (Sekaran & Bougie, 2016). As an initial step, interview records are transcribed into words. Transcripts were sent to participants and approved. Later, data coding has done which is an iterative process of deriving different combinations and meanings of words. The generated codes were grouped under the time, team, task, and transition aspects of projects. This also helped to form preliminary conclusions to display in the next phase of data analysis. Furthermore, the theoretical orientation (the 4-T Framework) explored in the thesis and desk research promoted the process of revising the set of codes.

Secondly, as Sekaran & Bougie explain that data display concerns the presentation procedure of reduced data in an organized way (2018, pp.336). In this way, it becomes easier to make use of categorized, summarized, and cleaned data. For this reason, the codes are grouped from the interviews and placed under the relevant component in the 4-T Framework. For example, the visualization by tables revealed common phrases such as performance measurement and project performance, which were combined later. For the qualitative analysis, the software *QDA Miner* was used to create and group the codes.

Lastly, the final and the most important activity of data analysis is drawing conclusions from the printed data. As the main objective of the research, observation of practices, and realizing themes and trends helped to answer the research question. Even it is classified as the last step, because of the explorative nature of coding, data display and conclusion drawing phases of data analysis conducted hand-to-hand. Data display was done by the word analysis. A table of final codes with the participant responses was formed. The frequency of mentions for the corresponding codes is then graphed for each project component and it was presented in Chapter 5. Additionally, from the selected quotes of the focus group, a word cloud was visualized to present the importance of different factors. It was included in Chapter 6.

In conclusion, the research methodology, which is the blueprint of the thesis, was described in this section in order to define a strategy on how to answer the formulated main research question and sub-questions.

3.4 Research Strategy

According to the stepwise data collection framework explained in this chapter, several research aims (Figure 8) are defined.

- The introduction and the background of the problem are given to have a preliminary understanding of the research topic. It is also targeted to introduce the theoretical baseline.
- A desk-based research method is used to identify project phases, data-driven tools, and the interactions between the technology and project management applications.

- Semi-structured interviews are conducted with key project participants to explore data-driven methods and their use cases in the management context. The importance of building data and their future opportunities are identified by transcribing and coding the interview records.
- Focus group discussion is carried out with project managers to validate the interview results.
- As a result, conclusions and recommendations are formed according to the data collected and analyzed. Thus, the main research question is aimed to be answered.

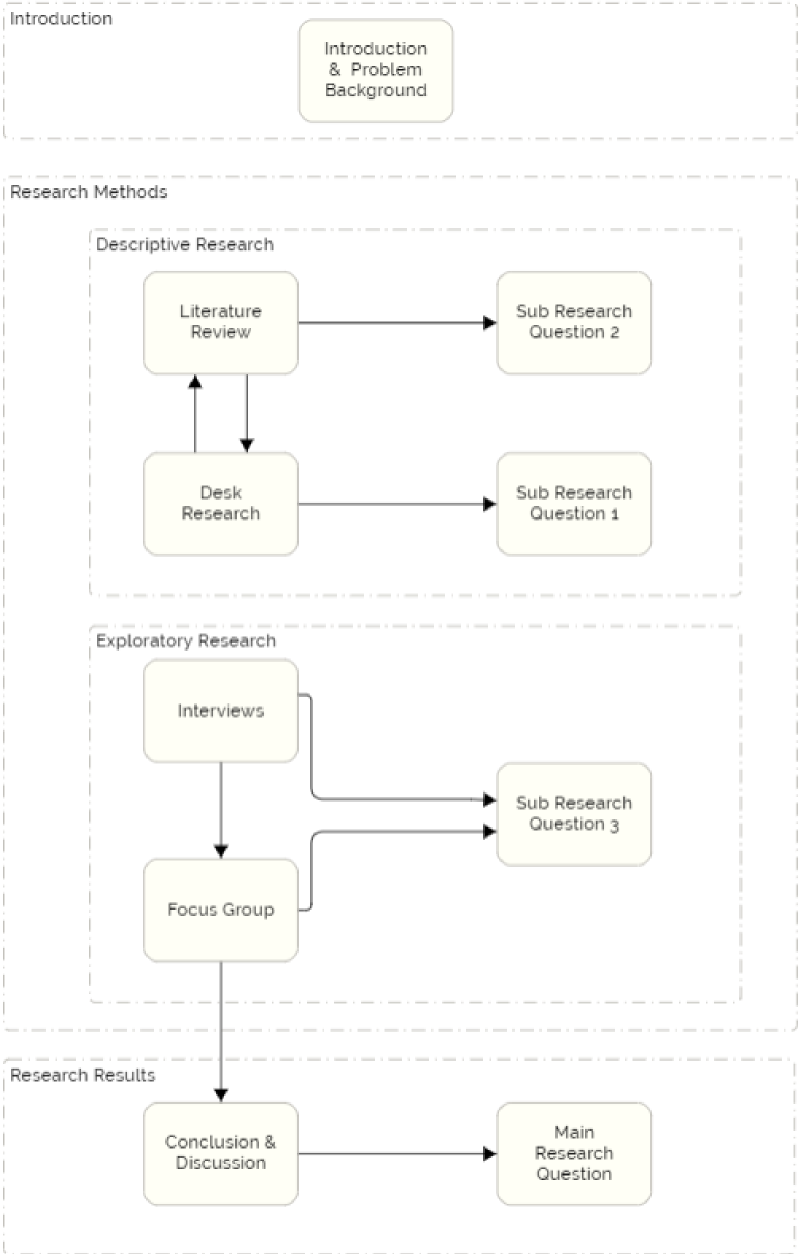


Figure 8: Research Strategy

4

Case Study Description

This chapter aims to present a data collection method by following traditional desk-based research. The information available in the organization's database is collected and grouped in a way that provides an understanding of emerging data-driven trends in the construction industry and algorithmic project management tools. In the end, by describing the case study the assisting research question was targeted to be answered:

> ***Sub-RQ 1: What are the current data-driven project management trends and applications in the built environment?***

To start with, the first sub-chapter examines the digital trends and standards in the built environment. Secondly, the following sub-chapter introduces the case company and relevant background information. The third section aims to address the project structure at Ballast Nedam by giving the context of project phases, and organizational structure. In the fourth sub-chapter data-driven processes, according to their purpose of use, are group parallel to the various project needs. The last chapter summarizes the desk research with a conclusion by presenting the information collected comprehensively. Conclusively, the desk research conducted will serve a preparation phase for the following data collection techniques.

4.1 Trends in the Construction Industry

The data process in the built environment means the documentation and information that is generated by the construction sites and offices. Data stacks can be found in paper forms, photos in different devices, written forms of change of orders, contracts, and interactions between different project participants. In this old way of managing construction, data was not well organized and isolated from the real-life factors. Eventually, there will be many documents but most of them go unused and are digitally useless. In return, emerging cloud technologies are developing to overcome this problem and address the need for data aggregation in a centralized way. Methods laying on the ground of the technology are employed inside the project phases by capturing and analyzing the construction data. For example, machine learning-based algorithms are becoming commonly used for prediction for different purposes. Integrated project management platforms, where connection and standardization of data procedures become possible, are also getting a remarkable amount of attention and are being implemented across the companies in the built environment (Higgins, 2018).

Similarly, construction management software is evolving to take the relevant information in and later by leveraging data to interpret both the single project and cross-projects performance. Historical information from past projects is used to evaluate the overall company performance and revising performance metrics regarding (Sylva, 2018) to stakeholder management and profitability. This can help construction companies to realize the room for improvement. However, one should note that centralizing and using the information as a management tool can be difficult for contractors. One of the main difficulties is that they may use multiple different information-gathering tools and technologies, but without a systematic data management and review strategy (Sylva, 2018), it is difficult to collect and use it powerfully.

In order to integrate information and create a common data management system, several standards are developing. buildingSMART is the worldwide industry body driving the digital transformation of the built asset industry and committed to delivering improvement by the creation and adoption of open, international standards and solutions for infrastructures and buildings. buildingSMART encourages international consensus among stakeholders on specific standards to speed up implementation. Standards cover "a wide range of process and information capabilities unique to the built environment industry'' (buildingSMART, 2019, para. 1). Similarly, international standard ISO 19650 offers a blueprint for information management including the exchange, recording, versioning, and organization data assets. The entire asset life cycle is covered in this framework, which contains the majority of the stakeholder roles involved. Standard also focuses on project management during the delivery phase (Scheffer, Mattern, & König, 2018).

Considering the advancements in digital technologies, the establishment of standards, and their effects in the built environment, Ballast Nedam defines its business objectives in the light of *digital construction sites* and *virtual buildings* themes (Ballast Nedam, 2018). Digital construction site concerns the increasing digitization of existing workflows, including reports on progress, documentation, and connection of devices, the addition of virtual reality technologies, logistics management, automated construction with scanners, robots, and drones. Virtual buildings refer to building a digital prototype at first. In addition to the 3D, scheduling and estimation aspects are included in the project specifications in the design phase. These form the foundation of information generation and gathering processes.

4.2 Ballast Nedam: The Case Company Description

Ballast Nedam is a construction company, which mainly operates within the Netherlands. The organization has become an entity in 1969 by merging of Ballast – a former sand extractor and later a construction company, and Nedam - a private building constructor (Merger of Amsterdamse Ballast Maatschappij and Nederlandse Aannemingsmaatschappij). After a public offer on Ballast Nedam shares in 2015, Renaissance Infrastructure B.V has become the main shareholder in 2016. Currently, Renaissance (Rönesans) is in the situation of the mother company. From the Hemmathagama water supply project in Sri Lanka to the expansion of the World Trade Center in Amsterdam, projects lie at the core of the company.

Figure 9: Company Divisions

The company structure, as seen in Figure 9, is divided into four broad categories, namely: *concession, construction, development*, and *industrial.* The unit of analysis in the case study will examine the construction division closely. *Construction* division, as a main contractor or subcontractor, is responsible for the successful execution of complex, integrated projects in both residential and non-residential constructions. New market exploration for international opportunities also falls into their professions. Ballast Nedam Construction (BNCONS) consists of two main branches: Operational Business Units (BU) and Technical Services (S). In total, there are 14 business units and 7 services with different department-wise categorization. The focus of this thesis research will be on the business unit of Building Projects. Under the Building Projects, design & engineering, and site engineering departments will form the unit of analysis.

4.3 Project Structure

4.3.1 Project Phases at Ballast Nedam

Firstly, the project structure at Ballast Nedam has its unique classifications. The sequence that is followed by the project team includes Design, Construction and Operation phases. Design both refers to design and tender, the construction phase includes coordination and execution and the operation phase is planned for maintenance (See Figure 10). The main PMBOK project management domains which are investigated around the setting of the thesis – Execution and Controlling & Monitoring - can be observed here from the tender until the end of the construction phase. Even though the phase of Controlling & Monitoring is defined as a separate step, it can be classified as the procedures and techniques to track the project while the project has been implemented. This justifies the project step classification of Ballast Nedam without a phase dedicated to monitoring and controlling. Rather, it has been applied under the construction phase, specifically the execution phase. The relevance of the identification of phases is to describe what phases are present and what are their similarities/differences with the developed guidelines. In this way, the project phase also refers to the task aspect of the studied framework.

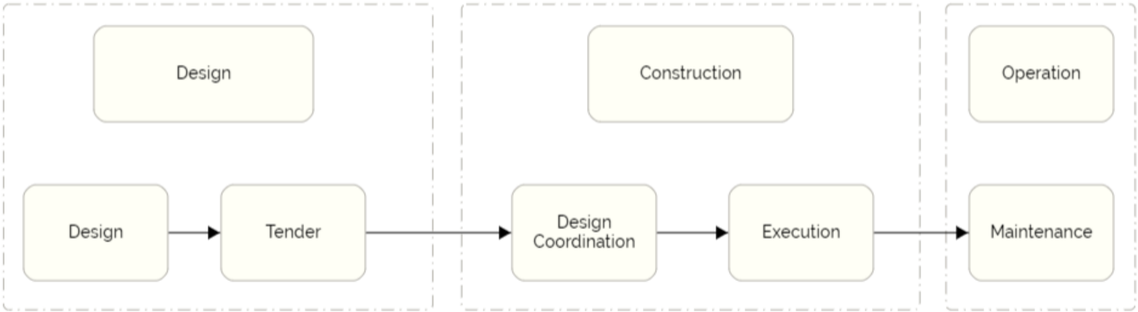


Figure 10: Project Phases at Ballast Nedam

In addition to the pre-defined steps or stages that are followed, the project sequence is also found to be dependent on the degree of maturity and the time of tendering (See Figure 11). More specifically, the project team forms a project management plan according to the project requirement that is defined in the tender phase. Within the organization, the decisions regarding the contracting and later planning are found to be affected by the following degrees of design maturity provided by the client (Ballast Nedam, 2019): SO (Structuurontwerp/Concept), VO (Voorontwerp/Preliminary), DO (Definitief Ontwerp/Final), TO (Technisch Ontwerp/Technical), UO (Uitvoeringontwerp/Execution) and Build Drawing. In terms of the steps that Ballast Nedam involves as the contractor, different execution scenarios can be drawn from the project initiation. Meaning that the project can start to be executed from various design levels. Yet, regardless of the level, tender links the project requirements to the construction phase.

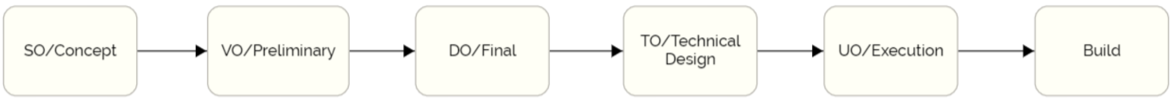


Figure 11: Design Levels and Project Phases

4.3.2 Organizational Chart and Roles

Branching from the construction division, the business unit of Building Projects has different levels of interactions (Figure 12) with Tender and (Building) Design and Engineering departments while executing and managing projects. The interactions during the tendering stage are found as the determination of design works scope, determination of budget for tender and execution phases, selecting and assignment of the project team and selection of the advisors, if necessary. These are all clarified by Building Design & Engineering and informed to stakeholders in the project. These interactions are found to be followed regardless of whether the scope of the project starts from VO, DO, TO or tender phase. The tender process is lead by the tender manager and it is the responsible body of all the coordinations and connections between clients and Ballast Nedam participants.

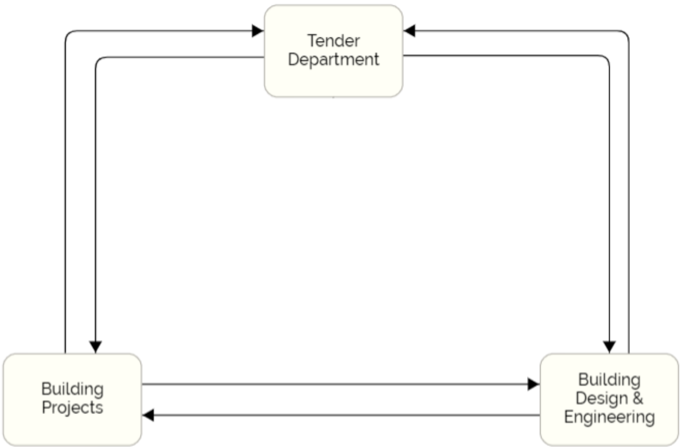


Figure 12: Interaction Between Departments

The interactions while the project switches into the execution phase are explored as the scheduling, determination of final execution budget and subcontractors, and the selection and management of the subcontractors. Similarly to the tender phase, the execution phase is lead by the project manager. Thus from this phase onwards, it is the linkage between clients and relevant company units. The explanation of the interactions can be observed as the existence of the team aspect, which gathers project teams and governance mechanisms.

After presenting the responsibilities and tasks related to the project management phases between tender and execution and division-wise interactions, the overall project structure will be explained for the project execution context. Even though each project is different from others, an organizational structure discovered to be commonly used as a project framework. Figure 13 represents the structure for Building Projects and it is chosen for the thesis research. The top two levels are Project Director and General Project Manager. Depending on a department-wise specialization different managers branch from and report to the General Project Manager. Of those managers, General Construction Manager is the executive lead of the projects that are being implemented. During the whole lifecycle of a project in the built environment Design & Engineering section, work preparators and construction manager are lead by the General Construction Manager. At Ballast Nedam the title Construction Manager also relates to the Site Manager.

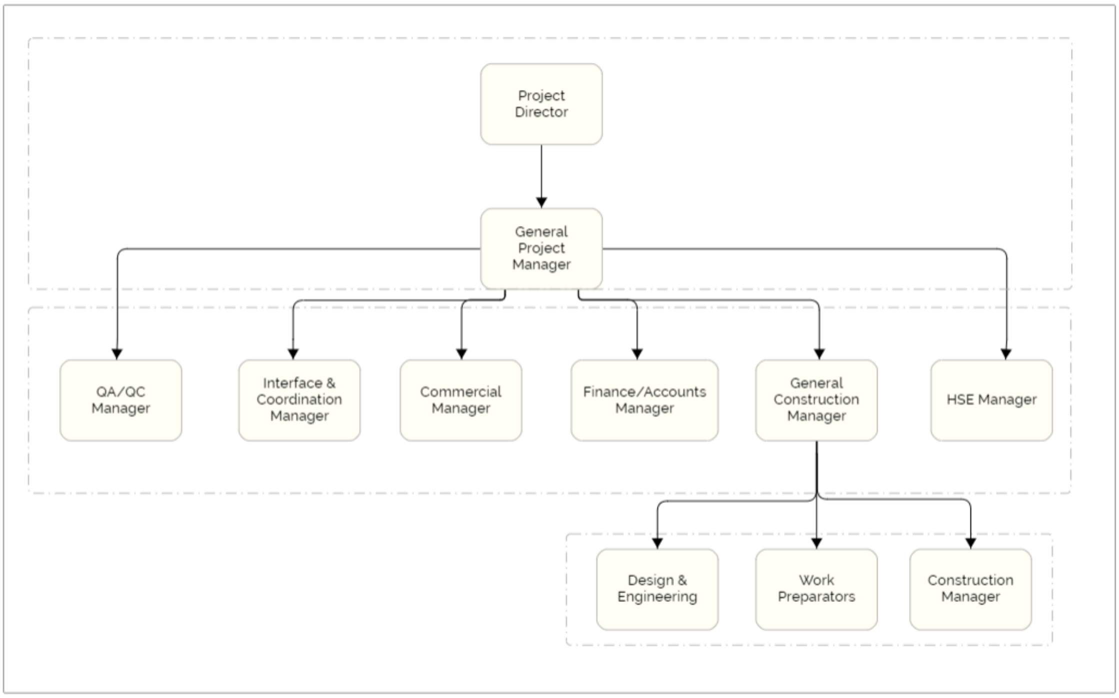


Figure 13: Project (Organization) Structure

4.4 Data-Driven Processes and Technology

Through the desk research data-driven approach was discovered to be related to the BIM environment, cloud-based management, management modules in the cloud platforms and software integration to fully the construction data. The following sub-chapter describes each data-related technology.

4.4.1 Algorithmic Project Management: The BIM Environment

To start with, Building Information Modeling (BIM) is a *"coordinated set of processes, supported by technology, that adds value through the sharing of structured information for buildings and infrastructure assets"* (The New Zealand BIM Handbook, 2019, p. 4). The model encapsulates applications of design, construction, and operation. Even though it seems as a designing tool, it does not only allow professionals and/or companies to visualize constructions but also let them consider other characteristics of the project.

At Ballast Nedam the link between engineering and architectural expertise and project execution is operationalized by the existence of BIM section as a sub-division of Building Projects. Along with the whole project team, the BIM department is responsible for the majority of the data empowered practices. In addition to the third dimension of drawing workflows (3D modeling or design), Ballast Nedam is currently employing BIM as a construction management tool for *coordination, quantification, 4D-Scheduling,* and *5D-Cost* (Ballast Nedam, 2019). These use cases found to be closely related to the integration of construction data. Thus, the sequential innovation steps, listed below, are being followed at Ballast Nedam, for a project to be successfully implemented:

- *Idea generation,*
- *Employing a pilot project,*
- *Evaluating results,*
- *Project realization, and*
- *Implementation* (Ballast Nedam, 2019).

Herewith, project stages are carried out utilizing previously mentioned five aspects of BIM. It is found both as a descriptive and prescriptive tool to manage constructions or building designs since it points out what exactly the process is and advice the steps should be followed. After the tender phase, Project Management procedures start with the construction phase where design collaboration and project execution are carried out simultaneously. Even though BIM notion can be relational to design and drawings at the first, it is rather a project execution mentality in which other divisions at the company use as one of the main project management tools.

Secondly, the rate of digitalization and innovations determine the practical use of data related tools and techniques and the market is abounding with different products and services. Therefore, there are numerous offerings and opportunities for companies to implement data-driven project management systems. Yet, within the scope of the case company, one becomes prominent – Autodesk®'s BIM 360™ (Autodesk, n.d.) platform as one of the main leading construction management software.

Thirdly, regardless of the role of the project participant and their physical location, it is found that the team can take part and can rip the benefits of using the collectively agreed management platform. Therefore, general contractors, sub-contractors, architects, building and design engineers and the project owner collaborates in a common environment and share, publish, change, assign, order and report data (Autodesk, n.d.) which are registered by other users.

4.4.2 Cloud-Based Management

When diving into data powered project management in the construction domain, it worths noting the importance of Common Data Environment (CDE) solutions and capabilities. As explained in the ISO standard of 19650-1:2018, CDE solutions are employed for both information and asset management. CDE allows users to monitor projects and information in three different stages, namely*:* working in progress, sharing, and publishing. It is found that the whole information model is not always held in one place, particularly for large projects, or widely dispersed teams. Information-based collaborative working allows CDE workflow to be distributed across different computer systems or technology platforms (ISO, 2018). Through CDE sharing information reduces the time and cost in managing coordinated information. Moreover, it was found that organizations can benefit from the information by producing, reproducing, reusing, and sharing, and changing content, if necessary.

At Ballast Nedam, being certified with ISO 19650 regulations, a cloud-based project management system is founded to be already implemented. Documents, drawings, models, rules and regulations with specific procedures, project assignments, tender and execution phases are carried out in a common data environment. Therefore, a unified platform where the project team can connect (even they are geographically dispersed) and keeping all the relevant project data help to manage projects in an organized way. In this way, it was explored that Ballast Nedam with the cloud-based management module shapes its project management around a shared platform. This helps the project team to improve the overall project quality, make informed decisions during the lifecycle of a temporary project, manage design and construction teams collaboratively and allows engineers to work on the same documents at the same time and save time while uploading, syncing and transferring large construction documents.

4.4.3 Management Modules

The cloud platform encapsulates different modules that are designed to be used for specific management purposes. The main motive of the platform found is to encourage the centralized data management system for user-tailored purposes. The management platform breaks down into sub platforms or so-called modules. Construction projects and workflows can be organized, connected and optimized using a single integrated platform where outcomes become profitable and predictable with improved decision-making (Autodesk, n.d.).

Herewith, the examination of the case company about the data-related procedures and tools about managing projects that are being used had revealed some of the major management modules. Even though each of them has a unit function and purpose, the integration of those management modules in the same cloud-based platform makes it possible to keep all project data organized and use it how and when it is necessary. Thus, the main management modules used in construction project management are found as Project Management, Document Management, Coordination & Collaboration, Data & Analytics and Cost Management. The following subs-sections will investigate each of the management modules with the project purposes and technologies they attain that are valuable to the project team.

Project Management

Procedures and processes concerning contractual issues and communication channels and standards that are used in projects may differ. In addition to these, managing several processes at the same and using different software may complicate the project management workflows. In the built environment it is nearly inevitable for documents to address all the issues sufficiently. These documents may include contracts, drawings and work specifications. Thus, knowledge gaps, ambiguities and conflicts may arise which require an additive procedure for clarification. A request for information (RFI) is defined as ‘’a formal written procedure initiated by the contractor seeking additional information or clarification for issues related to design, construction, and other contract documents’’ (Hanna, Tadt, & Whited, 2012, p. 1347). For this reason requests for information (RFIs) are used to address these conflicts, consequently, need to be managed properly in projects.

Team coordination, when communicated well, and tracking project progress have positive effects on scheduling and cost management in a project. Thus, with the existence of the construction management software, it becomes possible to record meetings in a central platform and provide reliable information for the meeting attendees when they needed. To use the project management module reduces the effort while creating, distributing and tracking the meetings on-time by making records available as a project component. It is found as a preventive sub-module that forestalls team members to miss crucial decisions or assignments made in the meetings. Therefore it was explored that through a single platform, changes can be managed and team coordination with recording meeting minutes can be ensured. It allows project participants to resolve conflicts and provides better scheduling.

Document Management

Similarly to the project management plug-in, documents can be managed by using the online BIM project environment. Incomplete, missing documentation, errors and discrepancies in the drawings and models may cause major rework processes, the frequent need for RFIs and schedule delays. Document management allows project participants to streamline building documents, regardless of the type or extension, and organize, distribute and share files according to their level of permission.

It was found that the distribution of project files mainly initiated by the upload and share tasks. Additionally, there is an automation feature in which publishing documents, models and sheets can be set in order. Drawing files can be searched for attributes they retain. By making document management centralized, accurate information can be accessed easily to avoid mistakes and wasting time. Documents, RFIs, drawings and models, specifications, and photos aggregate together in a cloud where documents constitute storage for data-driven analysis.

By controlling to drawings and documents project participants have a wide range of access to the information needed. On top of that, specialized searching features, when combined with offline sync capabilities on mobile devices give the whole team the ability to monitor documents even they are not connected to the cloud. Other benefits of using document management modules are found as standardizing the approval workflows, managing version history, and reviewing and commenting simultaneously.

While examining data-powered applications in the construction project management context, having documents organized and kept in one place and making the data available as much as possible is the initiation stage of having a solid database. Since data analysis to manage projects is based on the data itself, a centralized document management system is observed to be the foundation of data-driven applications. Ultimately, document management is not a separate module rather an aggregation tool to manage files in all of the modules to make a setup of a data warehousing.

Coordination and Collaboration

As different stakeholders work together in a construction project the coordination among them is one of the important and complicated issues. A project, if coordinated efficiently, can follow the schedule decided in the early stages and the company may save a huge amount of money since it reduces the change of orders and reworks processes. Thus, it was noted important to carry out coordination regarding project management, mostly for design issues, in a commonly agreed platform. Finding and resolving issues in the model is one of the main bottlenecks between design and execution phases. The design team from different disciplines can work on the same platform in order to handle clash detections. A well-coordinated project can deliver more constructible and reliable models, clarify the interaction among the multi-disciplinary communication.

Similarly to coordination, connecting teams in a common environment is one of the milestones of effective project and design management. Project team members can, when they work collaboratively, help to accelerate project delivery, eliminate rework and increase overall productivity by enabling them to author designs real-time and publish how the project data is exchanged. Therefore, the advantage of a collaborative platform at a management level was found strongly related to the decision-making where the deadline is trackable and coordination activities are recorded for team members.

Data and Analytics

An emerging module of the platform focuses the data collection, and use of data to monitor project and company performance and identify risks raised from project, stakeholders and the incumbent company. With the use of data science and machine learning techniques platform also offers predictive construction solutions. Even though the most updated plug-in of the platform is still in preview, the evidence from pilot cases is promising for organizations to implement these data-driven project management tools. The newest innovation gathers machine learning and artificial intelligence rules to help project managers about cost, schedule, quality, risk and safety.

It was explored that automating and digitizing current assignments and business workflows are not sufficient alone to dive into data-driven projects. There is a need for a single data platform to use and interpret the gathered information to drive the decision-making process. Here, reporting sub-module with predictive project management dashboard, steps in to meet this need of making cause analysis, ranking daily actions and sense-making of project performance.

Visualizing the project variables and data used to track progress and follow the necessary actions can be done by different types of reports and dashboards. This module allows project managers to view summaries of critical tasks and activities on subsequent workflows. While obtaining visibility of project situation with company-wide analysis business decisions become more clear and focused on direct objectives such as quality, safety and contractual issues. In addition to dashboards, detailed reports, summary reports, view and share reports found to be created to fulfill specific project needs. To fully benefit from the data-driven modules listed so far a conclusion drawing mechanism should be built, thus it is targeted to monitor project health, company performance, daily issue tracking and successfully interpreting of those outputs. With the well-defined management triangle Predict-Prevent-Manage, an emerging data-driven solution offers companies to fully exploit their information collected and stored in their cloud-based management system. Basing on the machine learning AI algorithm, the issues and risks can be identified and ranked which can be used to better explain the schedule, planning, execution, cost, quality and safety variables. Between data analysis and printing out results, a management module was found to extract and manipulate project data to use in computer-based intelligence algorithms. Instances on prevention tasks include viewing company risk to inform the project team and encourage improvements, subcontractor risk to evaluate their performance and take actions, and project risk to asses risk-attained issues and their possible effects. However, the data analytics step is still growing, and Ballast Nedam is found to be in the exploration phase of how to leverage project data.

Cost Management

In the built environment projects worth millions of dollars, thus managing cost-related variables and processes within the project management scope is crucial. According to the explored cloud platform, the calculation of budget control operations with the documents and data provided becomes more data-driven. The main management issue in construction projects is the change of orders (COs). A project, on average, may have dozens of change orders applied. Thus, it was found that the management of tracing COs during the whole approval process and examing the cost components and impacts on the project phases mean a great deal from the managers' perspectives. It was discovered that by using historical information from the database, simple contracts and customizable budget templates can be created automatically.

Field Management

Construction projects usually suffer from the disconnection between the site and the office. The work done or planned to be executed may not be followed adequately by the project executives. Additionally, checking the as-built and as-designed models can constitute a challenge if the changes and rework processes are not communicated timely. Thus, the integration of the real execution with physically dispersed participants is realized by the field management practices which can use additive equipment and software. For example, scheduling and estimation software, AI tools and cameras at the construction site ensure that the project team has a complete picture of the progress.

Therefore, controlling is an essential step of the projects in order to conclude whether they are success or failure. Thus, registration of the changes that are implemented on-site and following the execution of works whether they have complied with the procedures and drawing is called progress tracking. Two metrics are mainly used to control and monitor the progress: cost and time. PMKC[11] explains that Earned Value Management (EVM) is a widely used method for controlling the time and cost performance of projects with units of costs (Vanhoucke, 2011). Similarly, the Earned Schedule technique measures schedule performance in units of time. These metrics were found, when combined with the field data, to be utilized to monitor project performance.

Additionally, devices and machines are now getting smarter with artificial intelligence support. This situation can also be observed in the built environment from the examples of devices such as 3D laser scanners, augmented and virtual reality tools, drones and robots which are different data sources. While the execution of a project, it was found that the phase monitoring according to defined periods, is carried out by scanner. The real-time data captured by the scanners can be compared with the building models to check the compliance and control of the projects. In terms of the accuracy and scanning time of the devices as well as the project needs there various types of devices for reality capturing. Laser scanners and alike other tools, when integrated

[11] Project Management Knowledge Center

well with the software can be classified as the major technologies to link field application with project management.

4.4.4 Software Support and Integration

In addition to the cloud-based management platforms, many organizations and project teams are also using multiple software solutions, including ERP systems, cost control, and other business management tools (Venugopal, 2020). Thus, it is important to gather and use data from different sources. For this reason, most organizations prefer business intelligence tools that are capable of being integrated with the 3rd party solutions. With those smart tools, data, even though it is high-volumed, can be reported and visualized to indicate which project component requires more examination.

Therefore, the overall information management explored at Ballast Nedam receives input from different software pools, which are being used for varying project purposes. The software pools regarding Project Management Information Systems (Ballast Nedam, 2019) are grouped as listed[12]:

- Quality Management
- Document Management
- Record Management
- Service Management
- CAD
- Project Data Management
- Graphical Ports
- Planning & Estimating

Appendix A visualizes the grouping of the software pools, without addressing the commercial name of the solutions.

4.5 Conclusions: Data-Driven Process Exploration

In this chapter the first data collection method –desk research – was described. In order to understand the trends in the built environment on data-driven techniques and uses of project management practices, the information available was collected and gathered. Overall, in the light of secondary information organized the following sub research question was investigated:

- ***Sub-RQ 1: What are the current data-driven project management trends and applications in the built environment?***

Firstly, Chapter 4.1 presented the trends and standards in the built environment. Several emergent trends are founded important: digitalization of workflows, integrated project management platforms, construction management software for data preparation, and the establishment of international standards and procedures. Reducing the paper-based habits and transforming the data at hand to a digital platform where information can be interpreted meaningfully are the objectives that trying to be implemented by the project-based organization. Furthermore, most of the projects were currently not digitized this in return

[12] Financial Management pool is excluded due to confidentality reasons.

causes information to unused. To tackle this problem, project management solutions were emerging by offering a centralized way of gathering and communicating the project data. Meanwhile, organizations were trying to implement and realized the benefits of data-driven trends, internationally accepted industry-specific standards were also developing. This gives opportunities to permanent organizations executing temporary projects to formalize and configure their implementation in an orderly manner. Similarly, Ballast Nedam, with the innovations in digital technologies and the established standards, targets a number of themes including digital construction sites and virtual buildings.

Secondly, Chapter 4.2 described the company in the case study research and provided relevant background information. A brief history of the organization along with the main departmental structure was given as introduction. Later, the unit of analysis of the case – the construction division which executes the complex and integrated projects – was introduced.

Thirdly, in Chapter 4.3 the project structure at Ballast Nedam was investigated by explaining the current project stages and organizational structure for the building division. The project phases established by the project team identified as Design, Construction and Operation phases. Design phase both indicated to design and tender, the construction phase included coordination and execution and the operation step is applied for maintenance. According to the step where Ballast Nedam participated in projects as the contractor, different execution scenarios are found from the project initiation by the design information provided by clients: SO (Concept), VO (Preliminary), DO (Final), TO (Technical), UO (Execution) and Build. Furthermore, connected from the construction division, the interaction of the business unit of Building Projects with Tender and (Building) Design and Engineering departments were briefly explained while executing and managing projects and the common organizational structure was introduced to explain the project framework.

Fourthly, Chapter 4.4 identified algorithmic project management practices by listing various use cases. Thus, data-driven platforms, software and equipment, according to their purposes, were grouped by connecting them with the project stages. The BIM environment and cloud-based trends were explained to justify the use of data-powered platforms and their reasons. Thereafter, different management modules were identified based on cloud systems. The overview of the modules and their intended use listed in Table 5 below.

Table 5: Overview of Project Management Modules

Cloud-Based Platform	
Data-driven Module	**Contribution to the Project Management**
Project Management	• Defining and tracking information requirements • Scheduling and managing meeting
Document Management	• Organizing, distributing, sharing files and managing versions
Coordination and Collaboration	• Gathering different disciplines on the same platform and managing stakeholders
Data and Analytics	• Managing cost, schedule, quality, safety and risks • Improving decision-making
Cost Management	• Controlling budget and order changes
Field Management	• Tracking construction progress and evaluating project performance

Afterwards, the software environment, different than the management modules and cloud systems, was identified. It was found that organizations and teams may use multiple software solutions, thus there needs to be a linking step to connect all for adequate interpretation of the data generated. Correspondingly, the overall information system employed to connect different software and platforms is investigated.

As a conclusion, this chapter described the company and identified the current trends and applications of data-related tools for project management purposes. The information reached from one of the project presentations of Building & Engineering, can summarize the chapter and identifies the need to better use data-driven project management applications:

> *‘’There is a need for a well-established common platform and procedure to use the information for construction management. The information flow between the job site and the office is not yet at the desired level’’* (Ballast Nedam, 2019).

Conclusively, the desk research conducted will serve a preparation phase for the following data collection techniques. The next chapter will explain the interviews and present the findings.

5

Interview Results

In this chapter, interviews, the third data collection method will be presented with findings. Semi-structured interviews are designed to obtain people's personal opinions, experiences and interpretations on the data-driven approach for project management purposes. The main objective is to discover the status-quo and possible future motives in project management systems related to data-powered tools and techniques. Ballast Nedam has participated in the research as the main unit of analysis. Thereafter the pool of participants is defined under the Construction Division as described in Chapter 3 and 4. Interviewees included professionals with knowledge on construction project management dealing with building data. Prior to this primary data collection method, a desk research and literature analysis have been conducted to better structure the interviews by assisting with preliminary findings. By this way, Chapter 5 seeks to answer the following sub research questions:

- ***RQ3: How are the project components important while adopting data-driven methods to manage projects?***

The first sub-chapter describes the interview protocol defined. The second presents the interview findings. The last sub-chapter concludes the third data collection method and attributes meaning to findings. In the light of interview findings the fourth data collection method, a focus group will be presented in Chapter 6 and thus a validation process will be aimed.

5.1 Interview Protocol

The interviews are structured in light of the findings from the desk research and literature analysis. The current situation in the construction domain, as well as in Ballast Nedam is combined with the project management theory - the 4-T framework. Accordingly, this thesis applies a semi-structured interview protocol. This means, there exist constant questions to be able to compare interview results to increase the reliability of the research (Sekaran & Bougie, 2016). However, some of the questions were followed by the conversation that happened during the interviews.

As presented in Appendix B, the interview protocol includes the scheme of questions and the components that are attached to interviews. In order to present the research topic to the participants, an introduction was made on the data-driven project management. Additionally, an information sheet was sent to the participants (see Appendix C). Questions are divided into different headings to signal the transition, e.g. project management, data-driven applications, and insight-related categories. After the first part where the questions derived from the literature review are asked, questions regarding the data phenomena are directed. Lastly, the interview is finalized by the question on the future directions. Before closing the interviews, interviewees are asked if there are any points that they may think are important or are not addressed by the researcher during the interview.

As identified in Chapter 3, participants differ from each other in expertise and experiences. Thus, the questions in the interviews partially deviated for the concerned participant type. Project site engineers were specifically asked about progress tracking technologies in the project. However, the questions on project performance and model & design were direct to managers and project designers. In all, BIM managers and coordinators were treated as the project management link between the site and office, thus a distinction regarding questions was not made.

Since interviews include personal information from the primary source, there is a procedure to protect privacy and rights while keeping a certain level of transparency. In order to secure this, the interviews were supported with the informed consent form to notify participants about their rights and use of data. The GDPR form (Appendix D) provided from the Delft University of Technology (2018) was adopted and used for the interviews.

5.2 Interview Findings

According to the analysis of the information collected by the interviews, several key results are determined on the data-driven project management systems. Findings are presented by the theoretical base chosen in the thesis. Thus, time, team, task, and technology aspects of projects helped to group project-related findings (during the coding process). Under the first three components, prime factors are identified and combined with the technology aspect (Figure 14) which in turn assist to discover the status quo and future directions of data phenomenon in project settings.

Figure 14: Categorization of Findings

5.2.1 General Overview

After transcribing and coding it was revealed that all the interviewees agreed the existence of data explosion from various sources and the consequent transformation of data into meaningful information is to carry the businesses one step further. This can be related to the nature of workflows in the construction domain, where the change of works and orders and RFIs constantly happen. There are excessive amounts of data yet, the in-project applications are still not matured, consequently, it was observed that there is still a need to realize the concrete benefits of data-driven project management methods and tools.

As the participants agreed on diversified data generation methods in projects, the management of data and the knowledge on how to use or leverage will later be presented under the 4-T framework using the four components of projects. However, most of them mentioned the existence of a commonly used platform that allows project participants to work collaboratively with the gathered and organized data.

> *The technology, of course, will be evolved. But, the way people work together or share their knowledge, will always be important. -P4*

Similar to the findings from the desk research in Chapter 4, any innovation process follows a certain implementation procedure before it is widely adopted in the organization. These innovation steps in Ballast Nedam BIM division (*idea generation, employing a pilot project, evaluating results, project realization, and implementation*) on data-powered project methods were also mentioned during the interviews.

> *Ballast Nedam is willing to invest in innovations (..) But first, you need to have an idea and you have to try a pilot project (..). Then see what is the added value? Later you can dig into data. -P1*

5.2.3 Time Aspect

Project Values and Time

The time aspect of projects where milestones and objectives are set and used for different purposes was surprisingly mentioned as of lesser importance than other project components. Only P7 interpreted time as the main component of projects. This may be due to the nature of site engineers who are working in a dynamic place where they can witness the real progress and explain the improvements by time. Additionally, participants observed to be accustomed to delays, thus it may be due to the nature of construction projects where delays and cost overruns inevitably occur. Yet, the data-powered applications regarding time and combination with cost have been mentioned by some participants. Having project members as attendees from the BIM department, the 4th dimension of BIM modeling revealed to be one of the widest applications within Ballast Nedam. Thus the time component of projects is employed by project members in scheduling and planning workflows as additive leverage of information models.

> *The object has to be built in a specific week (..) we can visualize it in a 4D model, to see what should be done in this week. -P8*

Additionally, the time aspect of temporary organizations had found to have a strong relationship with the task, more specifically while measuring project performance. The participants expressed the time aspect with phrases like reducing additional works, process automation, deadlines, delivery dates, and schedule. Some of them referred to the internal procedures including project planning and master information delivery plan. As 4D BIM allows project planning to be visualized, items and components can be managed correctly, within the schedule, by graphical representation.

> *If you create more precise schedules, it means controlling the time for the project. -P3*

Regarding the values obtained from the project, most participants addressed learning points over time. The knowledge gained and shared during the whole lifecycle of the project mentioned by P4, P12 and P7 which can be used in future projects as an advantage. These findings are generalized as the use of historical data that was recorded during projects and become knowledge. Additionally, in line with the project values, monetary outcomes were also addressed in a relationship with time.

> *For all my procurements I do keep the schedule record and logs. Then financially, you can start with this data and win tenders with it. -P7*

> *Learn the lessons from a project. You need to provide the data for future projects. -P12*

In conclusion, the overall importance given by the participants represented in ratios below in Figure 15.

Figure 15: Time Components Importance by the Number of Participants

5.2.4 Team Aspect

Project Teams

Project teams consist of people with multidisciplinary expertise. First, this situation was ensured by including participants from different backgrounds to explore how they interact in different tasks and realize common objectives collaboratively. The configuration of project teams usually found to be shaped by the clients' or projects' requirements. Therefore, the requirements stated in the work contract defines the team formation to serve the project needs. P1, BIM manager, exemplified team divisions on projects by comparing high-rise buildings with housing projects. P8, digital construction lead, indicated that the teams he is responsible for have multiple specialists.

> *We plan a lot of different roles. There are coordination roles in the project, but also management roles depending on the requirement. -P1*

Another shared vision on the team component among the participants was on communication and collaboration mechanisms. Commonalities among the interviewees included progress meetings, common data environment, task definitions, responsibilities, and also procedural documents like execution plans, ISO standard, and QA/QC processes. Overall findings revealed that the team aspect with the technology aspect was found to be one of the most influential components of projects.

> *The most important part, in my opinion, is the team. If the team assembled for a project has good communication and coordination between them, then the tasks that are pointed to each member can be managed efficiently. -P4*

Even though it was not shared by all participants, some expressed their abstract perceptions of teams. Analogous to the findings in the time component, this refers to sharing a project culture, team feeling, and knowledge exchange mechanism.

> *I think the biggest benefit is the knowledge that you share. Learning from each other. -P7*

Project Governance

As a follow-up to project teams, the governance mechanism was also addressed by the participants. Governance is a management strategy supported by the documents and procedures in order to organize teams appropriately for the tasks specified in the project requirements. Professionals working in the office with coordinator and manager titles, as well as project and site engineers, they all involved in the governance steps, by performing defined project tasks which will later be evaluated. Thus, project governance of teams is found strongly related to the task aspects.

Managers and coordinators expressed the existence of an established governance mechanism that is shaped around *internal and external documents* and *standards*. Team governance and task definitions were found to be described by the documents including BIM Execution Plan, BIM Protocol, and responsibility matrix.

> *(..) described in a lot of different documents, the project planning, and the master information delivery plan where we track the progress of the different teams. The BIM execution plan where all the milestones are set, we use a responsibility matrix who is doing it what. – P1*

A differentiated discovery was revealed in the interview with P8. Because all the other participants were working on building projects. Whereas, P8's expertise is on infrastructural projects which had also been reflected on the team component. Therefore, this can be explained by looking at the construction contract types. In short, in addition to the design and build requirements by the clients, infrastructural projects often include the maintenance phase. Similarly, Ballast Nedam can play the role of lead designer, lead contractor, and financer. However, other project phases including execution and monitoring, share the same governance mechanism. To conclude, the general overview of the team aspect given by the frequencies of mentions was visualized in Figure 16.

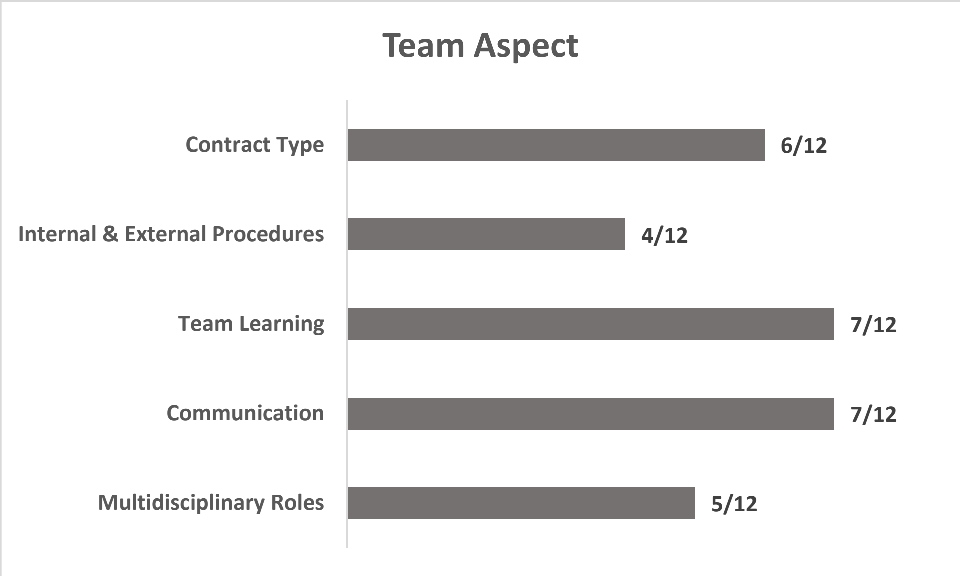


Figure 16: Team Components Importance by the Number of Participants

5.2.5 Task Aspect

Project Performance

Tasks are project assignments to the team members and the team itself. Thus, the interview findings on the task component of the temporary organization had always found to be inter-related to the team aspect. P3, with close to 10 years of experience in big-scale projects, addressed that the performance evaluation processes are important not only important for the defined tasks but also for the team itself. He also provided instances from quality assurance (QA) and quality checking (QC) procedures in order to evaluate project tasks.

> *QA/QC for the project elements and also for the tasks. This is something like assessment. (..). Because coordination of the project is dependent on team performance. -P3*

Similarly, P4 emphasized the link between task and team by the absorption of the core of the self-tasks and tasks of others. In line with his words on the project team being the essential component of projects, he described the task, team, and technology triangle specific to the team formation. Most of the participants, when they were asked about tasks, described the team meetings where they gather and evaluate project performance. Even though they have different opinions on how to hold a meeting and the frequency of the assessments, they found the lowest common denominator on performance measurement.

I think it's really important to do your evaluation with your own team.-P7

We have routine team meetings and within these team meetings, (..). we discuss the performance and tasks. -P2

Performance metrics in project management usually found to follow either a cost-driven approach or a schedule-driven approach. Thus, the task component, as associated with project performance, was also explored to be in relation to the time aspects. P4 and P8 explicitly mentioned that for evaluation criteria for project performance or project assignments, they use time-based and cost-based metrics.

The first way and the most common is the delivery date - deadlines as we know them. If a project can reach successfully the deadlines with the desired quality (..).-P4

It's a bit cost-driven and a bit schedule-driven but also it's driven by the construction site. -P8

Project Phases

Construction projects are executed to fulfill the ultimate task – project delivery. Under that task, the project breaks down into sub-tasks which can be called phases. Each phase has its own requirements and deliverables. Thus, to explore the task aspect interviews included questions about the project phases. Analogous to the findings of the desk research (Chapter 4), most participants mentioned the standard project phases defined within the Netherlands. These phases also determine the time where Ballast Nedam involve in the project and state the data requirements. For example, the tender phase where project objectives and requirements are set according to the contractual agreements is followed by several detailing phases which guide to the project execution. Additionally to these phases, as P8 indicated, Ballast Nedam might also take tasks on operation and maintenance phases.

Design stages are already set in the Netherlands like VO/DO/TO. In order to meet a milestone, we have to deliver a certain package at a certain stage. -P1

In addition to the external standards on project phases, it was found that Ballast Nedam has its own procedures and documents to apply their knowledge on construction projects. It was also explored that the alliances formed during the projects have also influence on the definition and application of project phases. P3 mentioned a project partner, which Ballast Nedam executes the Schiphol A-Pier project jointly, has a guiding role with its wide knowledge of airports. Thus, he expressed that their experiences, as well as procedures, were also adopted into the way that Ballast Nedam manages different project phases. P8, as infrastructural constructions concerns roads and bridges, added that governmental requirements and procedures can also be a determining factor of defining project phases.

We are working with TAV from Turkey. They had a rather big project before. For this reason, they have huge know-how on airports and internal rules. (..) We are trying to adapt to these procedures. -P3

There are protocols and standards we use, from Ballast Nedam, but also, from the government. -P8

Lastly, a shared vision on the client requirements was observed from the interviewees regarding project phases. As explained with the pre-defined stages in the country, Ballast Nedam takes over the projects where clients requests. Thus, in this situation the project phases to be followed by the client. The same definition was also addressed as the project type, where the involvement of the main contractors varies.

This has to do with the way we work or are integrated into a project. If you have a traditional project where the architect has the leading role, then the structural team is integrated at the later phase of the project. -P2

It really depends on the request of the clients. For example, in Schiphol, they want them as-built or as-construct. -P6

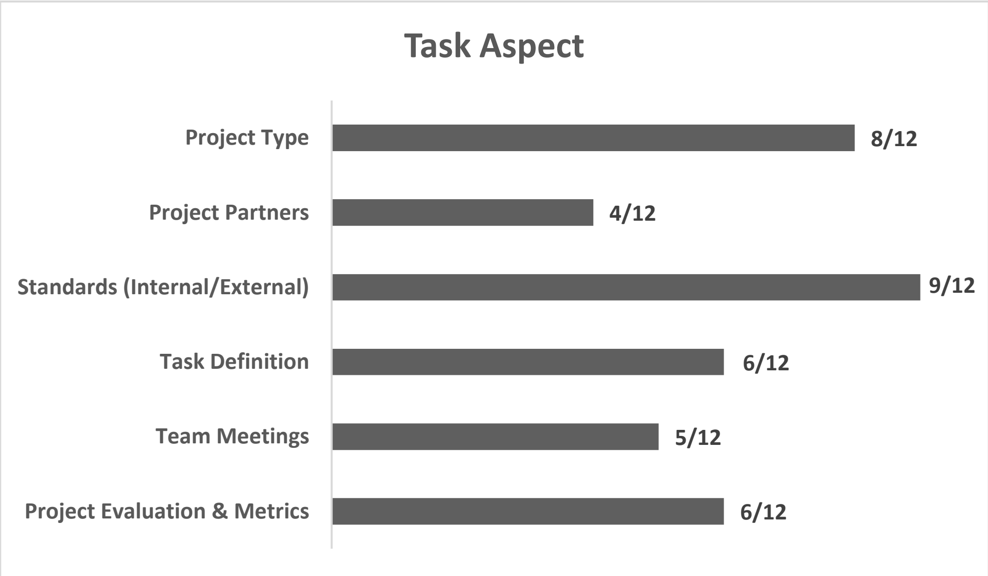


Figure 17: Task Components Importance by the Number of Participants

As the findings indicated the task aspect revealed important characteristics of projects. The fraction of importance mentioned by the participants can be seen in Figure 17 above.

5.2.6 Transition Aspect

The transition aspect was discussed as the technological transition to data-driven approaches for managing projects, and findings are grouped into two categories, namely: technology, and implementation strategy.

Technology

All of the participants pointed out some use cases of data-driven technologies according to their profession and job descriptions. Having participants from the BIM department, several model designing and project purposes were discussed to meet specific needs. Therefore, the link between project needs and software capabilities were pointed out.

To start with, BIM as technology can still be labeled as a new way of working as its improvement is going ahead in the built environment. A sharp changeover to 3D design from 2D has already been made. Additionally, BIM technology is there now not only for design purposes but also for the whole phases of construction projects, including planning, pricing, procurement, communication, and many others. Therefore, participants' vision of BIM justifies the capabilities and current adoption technology.

> *I see BIM as an asset. In the traditional working, engineers involved in the latter part of the project and the construction was limited because the design was ready. But with building information modeling, you integrate into the earlier phase where you can be more flexible with your construction. -P2*

Given the problem of construction project lagging behind the schedule and overruns the cost estimations, one of the main uses of the data with software is commonly mentioned as quantity takeoffs[13] among the participants. 3D models of the projects are used in software like Solibri to visualize quantities of materials and labor needs in detail. The additional step of quantities to the construction models referred to the data enrichment process by the users of the technology.

> *Solibri is also a data source and can make information take-offs where you can enrich data and push it back into the native files. -P1*

P3 and P6 additionally emphasized that it is now possible to use the quantification technology as input in other data-driven technologies to make analysis according to project requirements. Therefore, other data-driven tools such as Python and Dynamo use the outcome of the quantification process.

> *We have some quantity takeoffs from the building models. When you have some outputs from the model you can use these as the inputs for the other tools. -P3*

Additionally, again P3 and P6's visions were found similar about the integration of scripting and coding into the project phases. They were both found to be working on pulling information from 3D BIM models and IFC formats and manipulate the data which they find relevant for projects and the company in general. However, participants agreed that they are still experimenting and making trials to explore the capabilities and feasibilities.

> *What I'm doing in these weeks is exploring Dynamo and writing scripts to do the data enrichment back to the native models. -P6*

Similarly, participants shared their focus points which they are currently working on. These included future objectives as well. P3 and P6 are working on coding and data enrichment to use data for project purposes. Especially, P6's motives in data science tools become prominent. In contrast to others, he was observed to be the first adopters of data tools with hands-on experience within the organization. One of the emerging methods he mentioned was creating

[13] Measurement of labor needs and materails

a data frame and filtering the data from models and pulling data from different sources and creating reports.

> *I'm focusing on, first how to pull the data from the model and model authoring software. (..) The second is how I can use these data. For example for insights or for improving the productivity of the design team or construction team. -P3*

Lastly, regarding project phases of monitoring and controlling, participants shared common thoughts. They agree with the advancements in the monitoring technologies it becomes possible to progress project steps. Application range included terms like progress tracking, robots, laser scanners, and cameras and integrated software in the common data environment. The interviews revealed that progress tracking initiatives have already been tested and the company is aiming to spread it across to departments.

> *You can extract the output from the laser scanning and push it back to revise the model according to the as-built environment. -P1*

> *It is an efficient way to see if what you planned and what you gave for execution was done according to your standards. -P4*

Two complementary views have come to light regarding the use of progress data. In infrastructural installments and constructions, the general overview of the progress is being recorded. Because this relates to GIS where cameras capture panoramic views. Whereas in buildings the objective is to track the site progress where indoor capturing methods and survey equipment are also required. Two perspectives were also differentiated on the need for the accuracy of reality capture.

> *It is useful to record progress all day, with a video camera into the tower. You can see the delays, the mistakes and you can benefit from it. Because you have evidence for your client. -P7*

The mechanism of the progress tracking based on capturing points that represent coordinates of the components or parts built. Thus, the constellation of points, which refers to the point cloud, offers a huge volume of data source. By this technology, the site team and managers can visualize the project stages and update the 3D as-built outside. Besides the advantages of monitoring and controlling, participants also mentioned the dimension of point cloud data causes trouble in some cases. In the digital construction department, team specialists are exploring how to use point cloud data and overcome its limitations.

> *Some software is fairly promising, but, still, it can’t handle large data in which we are working. If I upload to point cloud of 15 gigabytes, most of the software programs are crashing at the point.*
>
> *(..).*
>
> *The point cloud will always be a point cloud. But how you handle that large volume of data, that's more important. -P8*

Interviews had revealed the different data sources which are widely used in construction. These data sources, as mentioned in the introduction (Chapter 1), are generated in various ways. Yet, with the tools and software used, the majority of the data which are digital, are coming from construction software. Therefore, participants all stated the existence of a huge amount of data that need to be filtered according to project requirements and communicated through the project members. Similarly, data acquirement from modeling and authoring tools, progress monitoring applications, scheduling software, geographical information, programming languages, and visualization tools are indicated.

Within the BIM expertise participants expressed their experiences on the project requirements linking with the information requests. Prior to the project takeover, different data sources as well as formats that will be generated and consumed during the whole lifecycle of the project, should be decided in advance in the tender stage. This avoids miscommunications during the execution by knowing the information procedures beforehand. Examples include the discrepancies between using 3D norms and adapting 2D norms and scheduling variables accordingly.

> *(..) it is important that the different sources of data to be defined before the project is started. -P4*

However, even the data and management framework are defined in a structured manner, the amount of data generated can only be used efficiently if it is organized well and accessible by the relevant project members. To address the issue, interviewees discussed the need for the combination process where the aforementioned software and data created by them can be managed. Ballast Nedam, being certified by the ISO 19650 Kitemark, is currently implementing common data environment applications in which not only the data is organized but also team members in the project can make use of the information registered. As mentioned in Chapter 4, ISO 19650 guides the information management in construction works, by setting concepts and principles as well as indicating the delivery phases of assets. It is valid for the whole lifecycle of the project from initiation to execution and maintenance. Therefore, the ISO framework is being implemented to standardize for exchanging, recording, versioning, and organizing information in Building Project division.

> *ISO 19650 is also integrated into project management, describing the processes and the steps that are needed in a project. Our BIM department is following the ISO 19650 standard. -P1*

Current practices within Ballast Nedam, as its implementation is still in progress, aims the single source of truth, where a document or a model is the only one and the correct one accessible by the project team. This term is found closely related to team communication and coordination among different parties, as they may find the relevant data where needed. All participants expressed the common data environment where it is structured to gather information and make better use of it for multiple people simultaneously. The folder structure in the company network was also found to be the earlier steps of data gathering.

For example, we are trying BIM360 in Ballast Nedam. It is a cloud platform where we store all the information that we have for a site, for a specific project. That means office documents, 3D models, 2D models, everything that we have, we store in one data source.-P4

Therefore, the applications and terms expressed and encapsulated by the common data environment that refers to central data management. Centralization means allowing each project member to access the same information or documents by using a single platform or tool in the pre-defined file locations. This offers a relative advantage in the construction domain since the contractor is not the one involved in the project phases. Other parties including sub-contractors and the project owner can also participate in the project environment and work collaboratively with the centralized documents.

Regarding the use of data, three participants described the open sources of information where companies can obtain and use to communicate with each other. For example, a buildingSMART initiative, OpenBIM, includes standards and workflows in the built environment for collaboration, design, and project execution purposes and accessible as open source.

There are subcontractors who are not willing to or capable of using the software we use. I always have to deal with them in some ways. OpenBIM is there the solution using a common format and does data exchange. -P6

We have open data that is, free and accessible by everybody in the Netherlands. That is a piece of building information, about the length and height, and the coordinates. -P8

Implementation Strategy

As observed so far, data-driven technologies are still emerging and they are considered as innovations. Thus, in order to start using the technology with all capabilities, an implementation process is being carried out. Similar to the section where the current situation is explained by the pilot project trial, the division Building Projects aims for a step-wise innovation mechanism where small phases are incrementally adopted to spread data-driven applications through the whole project. Participants, in line with their expertise, they are focusing on different ways of leveraging data in different phases of projects. For example, P1 mentioned, to switch fully using data previous innovations should become mature enough and the benefit should be realized concretely by the users of the technology.

(..). You need to do this very slowly. Because people easily afraid of these kinds of changes. -P3

We try to shape our database within the company and we would like to be competitive in the future tenders. -P12

Analog thoughts were also expressed by P8. He explained and emphasized on the incremental adoption of new applications where possible software and capabilities are explored in project settings. He, additionally, emphasized the validation process of their implementation strategy in the digital construction department where ideas are tested by the adopters of the technology.

If we think it's efficient, then we show it to some early adopters, who have already implemented it. Lastly, the technology often will spread itself, through the project and to the department. -P8

In addition to the innovation mechanism, participants shared their experiences on the implementation of specific data-driven technologies to manage projects. As explained under technology, implementation of a cloud-based common data environment, progress tracking applications by reality capture, and adding the schedule and cost as the 4^{th} and 5^{th} dimensions to the models are the main focus points of implementations.

Most participants pointed out that the standardization of processes and workflows as the leading objective. The interviews discovered that there are already countless sources of data in different stages and implementations to manage the project information. Yet, it was also found that project participants, even external to the organization, still use different frameworks or tools. Therefore, when the interviewees were asked to share their future objectives, most participants expressed the essentiality of standardization of procedures and the use of project tools.

By standardizations, I mean, develop a framework or develop a workflow that helps us do the same thing for every project and get the desired results. -P4

Analogous to P4, P6 and P3 also addressed the standardization stance. They mentioned standardizing data-related processes specific to the individual or team levels.

I believe that it is doable if we do our own data enrichment, and then we organize it in some ways in our own processes. -P6

First, we need to create and improve our processes, models and documents according to standards. (..). Nowadays, we are trying to describe every step for exporting and importing this IFC data to share with the parties in the project. -P3

P1, the BIM manager, indicated the importance of the ISO standard in the design and engineering department which is aimed to be implemented through the whole Ballast Nedam.

But ISO 19650 describes the processes and the steps that it's needed in a project. (..). We aim to implement the common data environment and to get the ISO standard through the whole Ballast Nedam. -P1

Innovative technologies are not without limitations. During the interviews, three factors were identified that obstacles the adoption of the data-driven practices in project settings. These factors concern technological, organizational, and individual aspects.

Regarding the technology, one of the leading factors mentioned by the participants was complexity. In order for people to understand the technology and offered software, the usage of them should not be that complex. Otherwise, it requires additional training and skills of which mentioned by P2 and P3. In contrast, P3 expressed his thoughts on the data-driven project tools to be of ease of use without demanding expertise in addition to the skills in the built environment.

(..) a lot of people will have to re-school or re-educate. -P2

The main reason, if you ask me, is complexity. If you can decrease complexity by being user-friendly and then you can change. (..) Otherwise, people can be caught up in this procedure of combining data without getting to a point. -P3

Secondly, some organizational factors, which influence the technological implementation negatively, addressed by the participants. Those included the company size and investment and management support. Some interviewees also found communication with different parties in inter and intra-organizational levels as an important factor in adoption.

Also, I think awareness of the management level. C-level. (..) If you are a huge company bigger R&D budgets are possible. They, of course, see the benefits, but you cannot focus on everything if you're a bit smaller. -P1

I'm facing a lot of subcontractors who are not able or who are not willing to do use the software we use. -P6

Surprisingly, nearly all participants discussed the human factor while explaining technological adoption. It means that not only the data-powered project applications are of high concern but also the employees who should work with them. Managers as well as project engineers who are in contact with people from different professions found the explanation phase of the technology to people and convince them as the main obstacles in the built environment, where most of the employees still rely on traditional project techniques.

The human being, is the weakest link, in this case, you have to get the attention of others and make them believe. -P8

The data collection is I think really hard for the construction site to embrace. They don't understand and see all of the benefits. (..) it is difficult to convince people to dig in data. -P1

Analogous to the findings on implementation, the phase of making individuals aware of the technology is commonly described with incremental changes. In order to spread the technology widely, participants agreed on first spreading the technology among the people and communication of those.

You are hearing me saying a lot about communication and coordination. I'm talking about people and I'm not talking about software. (..).. it is very important to find creative ways to make them see the benefit. -P4

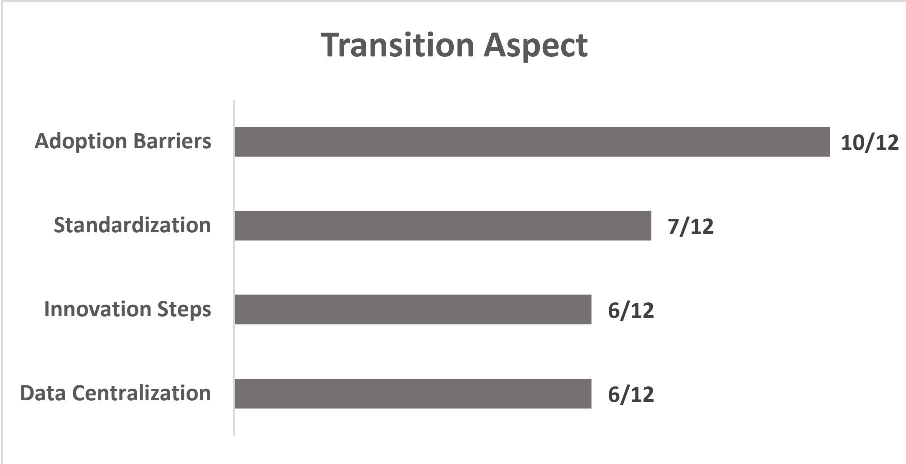


Figure 18: Transition Components Importance by the Number of Participants

The transition aspect was explored as the technological migration towards data-driven approaches for managing projects. Under the technology and implementation strategy categories findings were visualized in Figure 18.

5.3 Conclusions

This chapter presented the data collection method of interviews and their findings. In order to grasp personal experiences and reveal motives on the data-driven project management applications interviews were conducted with 12 participants with varying professions. Each lasted around 45 minutes. Thus, the chapter aims to explore project nature in the built environment and to discover data-driven technologies in project settings. At large, Chapter 5 searched answers to the following sub research questions:

- ***Sub-RQ3: How are the project components important while adopting data-driven methods to manage projects?***

To start with, findings from the interviews uncovered the existence of different data sources that are used for particular project purposes. The analysis of project components (time, team and task) and linking those aspects with the transition, or technology as adapted for this thesis, revealed that project constitution in the construction domain aims to visualize cost and time variables in order avoid or minimize delays and overruns by the collaborative teams. Besides, the main task – delivering the project – is shaped around the emerging data-related tools and applications. Data-driven project management practices are found to be currently implemented within the Ballast Nedam. Thus, as their innovation strategy indicates, significant steps, as well as barriers, were explored regarding technological implementation. Therefore, some of the influencing factors under the implementation category included pilot projects, project trials, department-wise adoption, and convincing people.

The overall findings which represent the link between projects (temporary organization) and the data-driven approach are visualized in Table 6. As explained in Chapter 2, the 4-T Framework was used to group the findings concerning each project component. Participants, from P1 to P12, were added into the table and their interpretation of the questions was incorporated into the table. ''x'' symbol represents that the participants mentioned the project component and considered it to be an influencing factor of project management. Marked boxes also indicate that participants use or trying to implement the aspects into their workflows. Blue boxes represent the participants from the Design & Engineering department, whereas green answers were given by the Site-Engineering department. Lastly, the construction data under the transition aspect marked ''x'' horizontally, since all participants agreed on the huge amount of data generated from different project tools.

Table 6: Interview Findings Based on the Project Components

<table>
<tr><th rowspan="2">Project Component</th><th rowspan="2" colspan="2">Findings</th><th colspan="12">Participants</th></tr>
<tr><th>P1: BIM Manager</th><th>P2: Project Designer</th><th>P3: BIM Manager - Site</th><th>P4: Project Designer</th><th>P5: Project Designer</th><th>P6: BIM Coordinator</th><th>P7: Site Engineer</th><th>P8: Digital Construction Lead</th><th>P9: Assistant Site Manager</th><th>P10: Technical Office Director</th><th>P11: Technical Cost Controller</th><th>P12: Commercial Manager</th></tr>
<tr><td rowspan="3">Time</td><td>Project Values</td><td>Historical Data</td><td></td><td></td><td></td><td>x</td><td></td><td></td><td>x</td><td>x</td><td>x</td><td></td><td></td><td>x</td></tr>
<tr><td rowspan="2">Cost & Time</td><td>Internal Checking Procedures</td><td>x</td><td></td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td></td><td></td><td>x</td><td>x</td><td></td></tr>
<tr><td>4D Scheduling</td><td>x</td><td></td><td></td><td></td><td></td><td></td><td>x</td><td>x</td><td></td><td></td><td></td><td>x</td></tr>
<tr><td rowspan="5">Team</td><td rowspan="3">Project Teams</td><td>Multidisciplinary Roles</td><td>x</td><td>x</td><td></td><td>x</td><td>x</td><td></td><td></td><td>x</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Communication</td><td></td><td></td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td></td><td>x</td><td></td><td></td><td>x</td></tr>
<tr><td>Team Learning</td><td>x</td><td>x</td><td></td><td>x</td><td></td><td></td><td>x</td><td></td><td>x</td><td></td><td>x</td><td>x</td></tr>
<tr><td rowspan="2">Project Governance</td><td>Internal & External Procedures</td><td>x</td><td></td><td></td><td></td><td></td><td>x</td><td></td><td>x</td><td></td><td>x</td><td></td><td></td></tr>
<tr><td>Contract Type</td><td></td><td></td><td></td><td></td><td></td><td></td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td></tr>
<tr><td rowspan="6">Task</td><td rowspan="3">Project Performance</td><td>Project Evaluation & Metrics</td><td>x</td><td></td><td>x</td><td>x</td><td></td><td>x</td><td></td><td>x</td><td>x</td><td></td><td></td><td></td></tr>
<tr><td>Team Meetings</td><td></td><td>x</td><td></td><td>x</td><td>x</td><td></td><td>x</td><td></td><td></td><td></td><td></td><td>x</td></tr>
<tr><td>Task Definition</td><td>x</td><td></td><td></td><td>x</td><td></td><td></td><td></td><td>x</td><td></td><td>x</td><td>x</td><td>x</td></tr>
<tr><td rowspan="3">Project Phases</td><td>Standards (Internal/External)</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td></td><td>x</td><td>x</td><td>x</td><td></td><td></td></tr>
<tr><td>Project Partners</td><td></td><td></td><td>x</td><td></td><td></td><td></td><td>x</td><td></td><td></td><td>x</td><td>x</td><td></td></tr>
<tr><td>Project Type</td><td>x</td><td>x</td><td></td><td>x</td><td>x</td><td>x</td><td></td><td>x</td><td></td><td>x</td><td>x</td><td></td></tr>
<tr><td rowspan="5">Transition</td><td rowspan="2">Technology</td><td>Construction Data</td><td colspan="12">x</td></tr>
<tr><td>Data Centralization</td><td>x</td><td>x</td><td></td><td></td><td>x</td><td>x</td><td></td><td>x</td><td>x</td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">Implementation Strategy</td><td>Innovation Steps</td><td>x</td><td>x</td><td>x</td><td>x</td><td></td><td></td><td></td><td>x</td><td></td><td></td><td>x</td><td></td></tr>
<tr><td>Standardization</td><td>x</td><td></td><td>x</td><td>x</td><td></td><td>x</td><td></td><td></td><td>x</td><td>x</td><td></td><td>x</td></tr>
<tr><td>Adoption Barriers</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td></td><td></td><td>x</td><td>x</td><td>x</td><td>x</td></tr>
</table>

Time Aspect

Project values and the cost/time combination were discovered under the time component of projects. The internal checking procedures regarding time, where workflows are combined with documents and software, was found as the most frequently. This justifies as evidence of well-established time monitoring processes. Furthermore, participants agreed closely on historical data usage and adding time as the 4th dimension in the visualized models. These two findings also addressed the applications of data-driven software and data recording. In this regard, participants mentioned that data that were consumed during a project is archived, and helps them to obtain new knowledge that can appliable for future projects. It was also argued that in addition to individual-level scheduling, project engineers and designers use widely the time-dependent variables, such as procurement of materials, in their project models. In general, scheduling and historical data approach were found to have moderate effects on the time component, consequently, time-related project applications were explored by the interviews.

Team Aspect

The exploration of the team component, both at the individual level and the collective level were made according to project teams and project governance. Project teams revealed elements including multidisciplinary roles, communication, and team learning. Whereas, the governance mechanism was discussed in directions of internal & external procedures, and contract. Participants expressed the importance of the individual roles and the communication manner among the project teams. Some participants exemplified their team communication systems, others addressed the management of stakeholders with different expertise. Similarly, more than half of the interviewees also found the learning perspective of the teams relevant, as they gave instances from project partners and adapting their knowledge into their own projects. Additionally, internal & external procedures and contract types were indicated regarding the governance systems of project teams. Four participants said the teams' governance is defined according to a set of rules both internal and external to the company. These include the project planning, BIM Execution Plan, and governmental rules. Additionally, the contract type which specifies the obligation of Ballast Nedam was also mentioned in lesser importance regarding the project governance. The contract type distinction was made by the participant who works in the infrastructural project, in return, he shared his experience of the additional types of contractual agreements comparing to the building projects. Herewith, project teams and project governance discovered to have significant roles in the team aspects, and the project settings in general.

Task Aspect

Falling under the main objective of project delivery, the aspect is uncovered with the project performance and project phases. This categorization justifies that companies take over and executes projects by following a set of phases and performance criteria. Performance of projects related to project evaluations and metrics, team meetings and task definitions. Furthermore, project phases analogous to the PMBOK guideline were identified by the internal and externals standards, project partners, and project type. Participants explained that evaluation metrics and team meetings have a strong effect on project performance. Having different assessment methods and regular meetings expressed as the essence of the task aspect. What is more, the definition of individual tasks as well as the interaction with others' tasks was also identified in the performance perspective. Similarly, project phases, as nearly all participants indicated, are currently followed by a standard set in the Netherlands. Some participants explained the specific phases they involve, including the tender phase and execution phase. Another important determinant of the project phases was found as the project type where the stage Ballast Nedam takes over the project specified. A few participants also addressed that the project phases may be evolved or adapted according to the alliances made with other partners. As a result, the task aspect was ranked as important as the team aspect when understanding the temporary organization.

Transition Aspect

The transition aspect was adopted from the 4-T Framework, in order to link the aforementioned project components to the data-driven technologies. Thus, covered by the transition, technology, and implementation strategy were explored by interviews. Sub-category technology included construction data and data centralization applications. Whereas, innovation steps, standardization, and adoption barrier were discussed under the implementation strategy. Construction data was confirmed to be generated from various sources and is high in volume and size. Regarding the technology, six participants named the common data environment where all the project information is organized and accessible by the project members. Furthermore, participants from the BIM department indicated a common data environment as a requirement of ISO 19650 standard which Ballast Nedam is currently qualified for. Regarding implementation data-driven technologies into project management workflows, some participants addressed the step-wise innovation mentality in Ballast Nedam. Nearly all participants who explained innovation strategy also touched upon the barriers to data-powered project opportunities. Lastly, interviewees discussed their current focus points and future objectives as establishing a standard way to communicate with each other and also with the technology itself. These objectives included instances such as implementing the common data environment and ISO standard for the whole Ballast Nedam. Eventually, the transition aspect, specific to the data-driven technology, appeared to be a determinant factor while discovering the nature of projects and adopting the data-driven approach.

6

Focus Group Results

In this chapter, a focus group, the last data collection method will be presented with findings. After conducting interviews in organizational settings at Ballast Nedam, the research topic at hand will be linked with managing-level participants' opinions who are experienced and knowledgeable about the construction management practices. As described in Chapter 3, Head of Building Design and Engineering and Head of BIM departments have participated in the group discussion. Thereby, the focus group gathers professionals with knowledge on construction project management dealing with building data. The main objective is to discuss the status-quo and future directions which are identified by interviews about the data-driven project management systems through capturing their perspectives. This is done around time, team, task and transition aspects of projects. While retrieving their opinions, a comparison is made with Chapter 5 results to validate and critically evaluate findings as well. Thus, similar to interviews, this chapter assists in answering the following sub research questions:

- ***Sub-RQ3: How are the project components important while adopting data-driven methods to manage projects?***

The first sub-chapter exhibits the focus group discussion. The second prints out the focus group findings. The last sub-chapter concludes the fourth data collection method and assesses the interview findings by making comparisons with a critical approach. Next, in light of the interviews and focus group findings, Chapter 7 will discuss the overall findings of data collection methods and concludes the research.

6.1 Discussion on Interviews

The focus group discussion was shaped by following the interview results. As structured in Table 7, the discussion included four main steps. The main objective of the focus group was to discuss the interview results to validate findings and revise where necessary. However, before presenting the interview information, focus group attendees were asked to express their opinions on two main components of the thesis research, namely, project management aspect and data-driven methods.

Table 7: Focus Group Description

Component	Focus Group Description
1	Introduction to the research and focus group, presenting informed consent
2	Presentation of critical components
3	Discussion on the interview findings
4	Conclusion

Firstly, the background of the problem and the research aim were explained along with the objectives of the focus group itself. Similar to interviews, to protect the privacy and ensure the use of information the informed consent form was presented.

Secondly, managers were asked about their opinion on project management performance in the construction industry. This step was done by following the project components. The four main aspects found commonly mentioned during the interviews were presented to participants.

Thirdly, by aiming to compare interview findings with the group discussion, interview results were exhibited. Visuals for each project aspect and results table were shared with managers to give them a complete overview of findings.

Lastly, in the concluding discussion, participants were demanded to make reasoning and interpret the findings. In this way, conclusions made it possible for a number of ideas to become prominent. As a result, the next section is dedicated to printing out the ideas and findings from the group discussion by different managers at Ballast Nedam.

6.2 Focus Group Findings

Similar to the interviews project management practices and their relationship with various project components were discussed and findings are grouped under the 4-T Framework: time, team, task, and transition.

6.2.1 General Overview

The results of the interviews were presented to the participants. Managers interpreted some of them as usual, such as the existence of standards, yet some results were also critically argued. For example, contract type in team aspect and project partners in task aspects, they were mentioned in a fraction of 6/12 and 4/12 respectively, in interviews. Thus, managers argued that their importance should be higher. Because contract type also brings key information requirements that shape the execution of projects.

Similarly, both participants agreed on the data generation and the emergence of data-driven tools. But, they both argued that the innovation speed is slow, consequently, the adoption of the data-driven applications in different project purposes is not still matured. Other prominent findings were recorded on the definition of tasks and requirements by the contract and project type. It pointed out that the projects should start in well-defined boundaries with clear requirements.

6.2.2 Time Aspect

Time aspect, as identified by interviews, gathers scheduling, use of historical information, and adding time component to the design models in the data-driven management scope. During the focus group, an emphasis was put on historical data where the information stored in the past can help future projects.

Historical Data

The recorded data, if it can be leveraged to use in future projects, become more valuable. Managers in the focus group argued that they should give more importance to create historical data. The project team generates a huge amount of data. Yet, because of the ongoing tasks and documentation procedures, M2 argued, most of the important information is being lost.

Similarly, M1 discussed historical data from the sustainability and technology perspective. It was argued that the know-how developed during a project is noteworthy. Yet, it should be stored and enduring. For this reason, the sustainability of the created information means the use of data not only for one but multiple projects in the future. Furthermore, it was found that, as M1 mentioned, Design & Engineering department is currently working on how to provide historical data by using data-driven technology.

> *For our department, design and engineering, historical data is one of the most important topics now. We are searching for how we can provide this by using technology. -M1*

Moreover, the scope of the ‘’historical’’ was further expanded by M2. He indicated that data can be classified according to the source and purpose of use. Firstly, a common understanding was discussed, as using previous project knowledge. Second, the information from tender phases was addressed to assist the execution phase. He also expressed that they encounter some information issues during the tender phase.

> *In the tender stage of the projects, there needs to be too much communication, agreements, or design changes. We are, most of the time, facing unregistered data, and we cannot trace back to the required information. -M2*

Lastly, historical data use in the execution phase was discussed. Monitoring step of the construction progress argued by the daily information registry, information changes, daily installations, or design changes. Then, these were linked to progress tracking which can serve as a tool for the management team. M2 also pointed out the need for collecting data in the same structure. Because it eliminates the need for data clearance or transformation.

> *It is an iterative process - gathering all the data in the same structure. Then you can track the history till the start day. And then you can make financial or statistical estimations. -M2*

6.2.3 Team Aspect

Two teams sub-aspects came forward during the group discussion: contract type and team learning. Additionally, task definition in the task aspects was also argued while deploying team roles.

Contract type

Regarding contract type, a critical argument was made. The focus group found the contract type as one of the major components of projects, whereas interviews indicated that only half of the participants found it relevant for project teams, or projects in general. Thus, here M2 argued the distinction of personal interpretation between managers and project designers or modelers.

> *From a manager's perspective, contract type, project partners and, evaluation metrics have more importance regarding data. For modelers or coordinators, it is another story. -M2*

Contracts where all the agreements and initial requirements were made, argued as the roadmap of the projects. Team requirements (roles), data necessities and partners were mentioned by the components of contracts. M1 discussed the importance of determining the contract type with the client. He referred to this as demarcation.

> *The demarcation of contract type is very important. You have to determine it with the client. Everything starts with the contract. -M1*

M2 extended this perspective while arguing the data requirements. Because the software uses, drawing standards, information delivery, information exchange and sharing criteria are defined in contracts. If those are not defined collectively with others and there exists a discrepancy between sources then problems regarding data management may arise.

> *If you haven't defined your data requirements properly in contracts, then at the end of the project, the output of the data or required structure is not going to be there as well. -M2*

As managers argued, contract type was also found to be related to task definitions, project partners and performance standards. Thus, the relationship between the team and task aspects explained in 4-T Framework was also pointed out.

> *You create a system with task definitions according to your contract. According to your contract, you evaluate performance and you can execute the project with partners. -M1*

Team Learning

Firstly, M1 repeated his vision of historical data for the teams. He pointed out during a project knowledge is created and shared. However, in order to benefit from team-level learning, it should be sustainable for the company. Thus, interaction among the team promotes and generates project know-how, consequently, the information should be applied in the management of sequent projects. It was also argued that the contract type can also determine the learning processes. Many projects are executed according to a project plan specified by contracts. These contracts define the teams, roles, responsibilities and the use of personnel resources. Therefore, the contract type forms the teams and affects team learning.

Similarly, M2 asserted the learning from a general contractor perspective. He argued that projects are temporary and unique. Thus, there is a need for new team formation for different client requirements, contract type, and data specifications. It was argued that team learning is not as high level as the other sectors. In such an environment where teams are temporary, project teams apply different workflows to the varying project needs.

For each project, we should set up new teams, and these team structures should be unique to the project. (..) In general contractor companies, the tasks are uniquely defined and, flexible for the client and data requirements. -M2

6.2.4 Task Aspect

The task aspect refers to the goals and assignments which are defined by the project scope. It is related to the project performance and phases, as found in Chapter 5. The focus group emphasized on project evaluation, task definition, project partners, and project phases.

Project Evaluation and Metrics

Managers interpreted team performance with evaluation metrics. According to the findings from the interviews, half of the participants mentioned the importance evaluation mechanism for project performance. But, a commonly agreed standard or criteria for this purpose was not found. Following this, the focus group participants addressed the temporary nature of project tasks. In each project phase tasks are defined and revised constantly, thus most of them are assigned to solve ad-hoc issues. Therefore, M2, argued that the task is not standardized thus their evaluation is somehow problematic as well.

Tasks are coming to solve short term problems. Most of the times the outputs of the tasks are not necessarily referring to standards or a template. So, it is hard to gather those outputs and create a readable data format. -M2

Task Definition

The focus group discussion indicated that the task definition comes with the contract type. It was argued, the demarcation of tasks should be one of the priorities of the project managers. In this way, the tasks need to be distributed among the team, data requirement of tasks, the tools to execute tasks will be defined.

We are making a demarcation - the task definition. I think standards and team meetings are important, but everything starts with contracts and tasks definition. -M1

On contrast defining tasks in advance, as mentioned before, tasks are appointed to solve unique project requirements. Therefore, the degree of standardization of roles and tasks is limited in the built environment.

We always have unique projects and unique teams. All the time, again and again, different tasks are given among them. That's why standardization is the biggest required aspect for data management or creating a structure. -M2

Project Partners

During the focus group discussion, project partners in the task component argued several times. First, when managers discussed contracts and requirements the importance of project partners was touched upon. Because they also involve in the project and have different working methods. M1 provided an example of project partners and linking them to project phases.

We have some problems with partners, especially, at the UO stage in Holland. -M1

As described in Chapter 4, there are several standard project phases in the Netherlands. During different phases, Ballast Nedam may work with external partners. Therefore, they may have different capabilities and requirements as well. For this reason, it was found important to consider project partners and their information delivery mechanism to the organization.

> *We are sharing some project parts especially for the structural components, and precast. Later, DO is prepared by our subcontractors. They are also responsible for shop drawings, and 3D drawings. So, their quality and their movement are very important for us. -M1*

6.2.5 Transition (Technology) Aspect

The transition component of projects is described as the technology and implementation strategy. During the group discussion data-driven technologies in projects argued by the manager from the following sub-aspects: standardization, innovation steps, and adoption barriers.

Standardization

The standardization of the technology is looked at from a different perspective by the Head of Design & Engineering. He argued that standards are of high priority in the Netherlands and found the findings of the interviews (7/12 for standardization) too low. Furthermore, he questioned the standards in the task aspect (9/12 for standards). Because, as he discussed, regardless it is for tasks or technology standards could be better aligned.

> *Standardization is very important in Holland. Because the technology is backed up by good contracts and clear task definitions with project partners. -M1*

Similarly, M2 deliberately argued that the level of standardization for data-driven technologies is rather lower. Data analytics is improving, and there are different data sources in the built environment. Yet, the industry still lacks to develop a common understanding of those tools for management purposes. Thus, standardization was further discussed under the adoption barriers.

Innovation steps

Regarding data-driven innovation in projects, participants discussed two main arguments. The first one was about the slow rate of innovations in the construction industry. The second one addressed the necessary steps to successfully implement data-powered project practices.

> *If I speak, frankly, such kind of innovations in the construction business goes very slowly. Our market comes behind the markets like the automotive sector and manufacturing. -M1*

The Head of the BIM department drawn attention to data requirements. He listed several steps for data-driven applications, which they are trying to accomplish within Ballast Nedam. These steps included structuring data and adding those into the information requirements and task definitions.

> *If you structure your data and get this into your task definitions, also in data requirements then the technological barriers would be easier. Most of the time we are having that issue. Because we are not producing output in a structured way, and we cannot fully get the benefits of technological tools for data management. -M2*

Adoption Barriers

The technological complexity, lack of training, scattered data, and convincing people were the main findings on barriers after the interviews. Some of them were also expressed by the focus group participants. M1 mentioned that some of the site-engineers are not trained well to use BIM-based technologies. This, in turn, prohibits the data-powered tools to be spread over the team members. Also, since it requires additional time, it negatively affects the efficiency of the workflows.

> *Finding trained people is an obstacle to the construction market. Even in our company, many werkvoorbereiders are not accustomed to BIM technology and, it makes us lose time and efficiency. -M1*

A different approach was suggested by M2. He compared two categories in the transition aspect of the framework. In this way, it was suspected that standardization and adoption barriers are connected to each other yet, in an opposite way. He discussed that the tools and techniques are matured enough to use, however, the industry lacks structured data or standardized data. This, in turn, constitutes a challenge for data-power project practices.

> *If the standardization gets higher adoption barriers will be getting lower. Because technology is there and tools are improving. But we are at the same spot where we were 10 years ago. Because we cannot produce structured data. -M2*

6.3 Conclusions

The focus group discussion was held with two managers from Ballast Nedam, Building Projects, and took 58 minutes. The aim was to grasp personal opinions on data-driven project management applications and validate and revise Chapter 5 results by interviews. Thus, similar to interviews, this chapter investigates the sub research questions below:

- ***Sub-RQ3: Why are the features of projects important while adopting data-driven methods to manage projects?***

After the analysis, some results become prominent. As seen from Figure 19 below, a word cloud is formed from the personal quotes of group discussion. According to the frequency of mentions, ***contract type, historical data, task definition, technological standardization,*** and ***adoption barriers*** were found to be the most influential sub-components of projects.

Figure 19: World Cloud Analysis

Contract type refers to the team aspect by project governance; historical data refers to the time aspect by project values; task definition refers to task aspect by project performance, and; standardization and barriers refer to transition aspect by implementation strategy.

Contract Type

Managers in the focus group expressed construction contracts as the starting point of every project-based activity. Contracts include what needs to be done, who should participate in, what are the client requirements, and how the information flow should be communicated. Thus, one should consider the data requirements defined in the contract when focusing on data analysis. These data requirements in contracts encapsulate drawing types and formats, use of BIM models, design change specifications, material codes, and most importantly the exchange mechanism of information among the project members. Therefore the contract itself and the type were found as the key component of projects.

> *We started to define the data requirements in the contractual documents more and more. -M2*

Historical Data

As for the time component of projects, historical data discussed by the participants. Ballast Nedam is currently focusing on leveraging past knowledge into future projects. Some obstacles were also identified regarding the data management system. These are the existence of different data formats from various and data being in an unstructured format.

> *We trying to use the tools which can make data changes and data transfers more visible and reportable. So, for the themes and objectives, we are trying to create the base for the future.-M2*

Task Definition (Demarcation)

Regarding the task aspect of projects, the demarcation of project roles was argued with the contract type. As the requirement initially comes with contractual agreements, the task definition was also found dependent on contracts. Thus, an organized contract addresses the task demarcations clearly. However, task definitions and standardization of tasks argued as conflicting views. Because, as M2 expressed, projects in the built environment are temporary and are not identical. Each project has unique requirements and this demands a unique formation of tasks. Therefore, it was found challenging to express tasks in data formats or quantification. Another sub-component this discussion born was the project performance. As tasks are specific to projects, the evaluation metrics do not also meet the standardization requirement of data-driven tools.

Standardization and Barriers

Lastly, a notable discussion was made on the transition aspect. Both participants argued that the standardization of the data-driven applications and barriers to adoption were related. It was mentioned that the lack of well-trained personnel as the current problem they are facing with. Additionally, a remark on the gap between the technological growth and the actual use was made. It means the built environment is lagging behind to implemented data-driven tools and methods given the advancements in the technology. The low level of standardization was also discussed as the main factor for this.

However, managers pointed out the implementation of cloud-based technologies within the BIM department in order to centralize data management. This concerns the real-time use of project information by the members in a common data environment. Similar to the other aspects, the need for structured data was discussed as the pre-requisite of the standardization.

> *We are trying to adopt cloud platforms, in order to move data or information delivery cycles to the common data environment structure. (..).*
>
> *If you do not create structured data and structured output, we won't get anywhere. -M2*

Other Project Components

The discussion also included other components of projects. The discussion for all the aspects was summarized in Table 8 below. Among those, team learning was advised to be sustainable in order to use the knowledge continuously. But, this was tackled by the unique nature of construction projects where knowledge obtained cannot be applicable for other projects. Project partners were discussed as the subcontractors and as a determinant of project phases. Participants lastly mentioned innovations steps by comparing the innovation rate in other industries with the built environment. The need for structured data and transforming data into information were argued as the preconditions of data-driven innovations.

The next chapter compares and discusses findings from Chapter 5 and 6. It also employes the 4-T framework to interpret the results on project components and their relation with the data-driven approach.

Table 8: Participants' Opinion on Project Components

Project Component	Findings		Participant's Opinion: M1: Head of Building Engineering	Participant's Opinion: M2: Head of BIM
Time	Project Values	**Historical Data**	Currently working on how to provide historical project data	Data registry and structured data to track the progress
Team	Project Teams	**Team Learning**	Know-how should be sustainable	Not high as other industries because of the unique requirements of projects
Team	Project Governance	**Contract Type**	Demarcation of contracts with clients and relates to task definitions	Defining data requirements well in contracts
Task	Project Performance	**Project Evaluation & Metrics**	-	Tasks are not standardized thus proper evaluation is an issue
Task	Project Performance	**Task Definition**	The first requirement coming with contracts	Different task definitions for each project, thus standardization is required for data management
Task	Project Phases	**Project Partners**	Working with multiple subcontractors in different phases of projects	-
Transition	Implementation Strategy	**Innovation Steps**	Comparison of industries	Creating structured data, placing them into task definitions and information requirements
Transition	Implementation Strategy	**Standardization**	Standardization is valuable in the Netherlands and comes with contracts	Linked with adoption barriers and unstructured data
Transition	Implementation Strategy	**Adoption Barriers**	Lack of trained people	The gap between the use of technology and technological growth

7

Discussion & Conclusion

This chapter draws attention to the interpretation and importance of the collective findings from Chapter 5 and 6. Interview and focus group findings are evaluated and meanings are ascribed to the results. The results are compared with the relevant studies conducted in the past. Furthermore, it forages the suitability and applicability of the research strategy and design and as well as limitations in a critical manner.

The remainder of the chapter is as the following: Section 7.1 outlines and discusses the identified data-driven project management practices. Next, answers for the research questions are provided in 7.2. Section 7.3 relates the findings with the previous literature and points out managerial implications for the organizations. After, section 7.4 discusses the limitation of the research. The directions for future research are recommended by 7.5. Finally, the chapter ends with a section where a reflection was made upon the research process.

7.1 Data-Driven Project Management (DDPM)

7.1.1 Time Aspect

Under the time component project values and time/cost relations were explored. Interviews revealed the data usage in internal timing processes, scheduling dimension of design models and historical data. Scheduling and historical data both addressed the data-driven software and data recording. Data creation, storage, and use for future projects mentioned by participants. However, it was found only at individual levels. On the other hand, focus group findings did not emphasis on scheduling and controlling procedures. Rather, it revealed the transformation that Ballast Nedam is targeting. Collective findings suggested that the creation of a data baseline to use structured project information is one of the focus points at Ballast Nedam. In this regard, it was found that data-driven tools can help companies to leverage historical data. In addition, visual data-recording also classified as historical, which is used to track the construction progress. Lastly, both interviews and focus group pointed out historical data can also promote learning both in individual and team levels. The collective findings are printed out in Table 9 below to show the contribution of data-related application into the time component of projects.

Table 9: Data-Driven Technologies in the Time Aspect

Time Aspect	**Historical Data**	• Creating a database of previous projects • Using past knowledge in the future project • Storing information and providing team learning • Tracking construction progress with daily information

7.1.2 Team Aspect

The team component for data-driven applications addressed project teams and project governance. Even though multidisciplinary roles, communication, and team learning were discussed commonly during the interviews the focus group only argued on the learning sub-aspect out of these three characteristics. Team learning, as it is linked to historical data use, suggested to be sustainable. It was argued that the knowledge obtained and shared can only be meaningful if it can be transferred to the future. However, focus group findings also addressed that each project is unique and the learning at the team-level cannot be applicable for different projects. Both interviews and focus group agreed on the procedural documents where the project governance mechanism is determined. This can come by the client, BIM documents and governmental rules. Thus, information requirements are of high importance. In contrast to procedures, a discrepancy was observed for the contract type. During the interviews, only half of the participants responded contracts as the determinant of project governance. The managers in the focus group found it the most important component of construction projects where everything is discussed and agreed upon for the project. It was found that information delivery and exchange system, the definition of the task as well as data requirements start with contracts. As seen from Table 10, the contract type and the procedures were found to be determinant factors of the data-driven application in the team aspect.

Table 10: Data-Driven Technologies in the Team Aspect

Team Aspect	**Internal & External Procedures**	• Documentation of Project Requirements • Procedures including, project planning, BIM Execution Plan and governmental rules
	Contract Type	• Defining data requirements (drawing type, format, material codes) • Defining task definitions (demarcations) • Identifying information delivery and exchange mechanism

7.1.3 Task Aspect

The main objective of the project-based organization is project delivery. While delivering the project, certain tasks are being defined and assigned to the teams and individuals. Thus, the task aspect of projects was analyzed by project performance and project phases. Project evaluations and metrics and team meetings that were explored during the interviews have revealed to be lesser important by the focus group. Because, it was argued that tasks are coming to solve short-term assignment, consequently, data-driven project evaluation becomes problematic. These ad-hoc tasks differ per project and per team. However, the biggest focus was on the task definitions. Interviews showed that tasks are chosen and distributed according to the project needs. ISO 19650 standard guides this process by defining both task and information requirements of project teams. Furthermore, the focus group also validated this perspective. Managers in the group again referred to the contractual agreements, where task demarcations are outlined.

Similarly, project phases were discussed both in interviews and the focus group. It was found that project standards specific to the Netherlands are being followed. BIM Managers explained the specific phases they participate in, such as tender and execution. Lesser importance is given to the project partners in the interviews. But, the focus group argued the subcontractor requirements for specific phases can also be important. This point of view was linked back to the project contracts where partnerships are defined and initiated. For the task aspect of projects, definitions of tasks, and project phases (Table 11) were discovered as the most important factors while adopting the data-driven approach.

Table 11: Data-Driven Technologies in the Task Aspect

Task Aspect	**Task Definition**	• Defining requirements of tasks and interact with others' tasks (ISO 19650) • Comes as a result of contractual agreements • Tasks are unique - Evaluation criteria and standardization need to be tailored according to the project needs
	Project Phase Standards	• Commonly agreed phases in the Netherlands • Defining by the contract type (maintenance, operations as additional phases) and includes project partners

7.1.4 Transition (Technology) Aspect

In this thesis, the transition aspect from the 4-T Framework was adopted as the technology. The objective was to link the other project components to the data-driven technologies. For this reason, the transition aspect outlined as technology, and implementation strategy. The technology was discussed by construction data and data centralization. Under the implementation strategy, innovation steps, standardization, and adoption barrier were addressed.

Construction data was identified as the generation of high-volume and size data from various sources. Both interviews and focus group agreed on the emergence of data generation and addressed the unstructured forms which require for standardization. This unorganized format of data may come from drawings, BIM Models, contracts, procurement lists, material specifications, and 3D laser scanners, as mentioned by several participants. Interviews uncovered the common data environment as the main implementation step. It comes as a requirement of ISO 19650 standard where all the information-related workflows are carried in a cloud-based platform. It was also identified as one of the innovation steps regarding data management. Because the first step was already taken for Ballast Nedam by establishing and complying with ISO standard. It outlines how information storage, delivery and exchange should be carried out. Moreover, most participants who advocated innovation strategy also named some barriers to data-powered project applications. These included personal capabilities and convincing people, the pace of technological advancements, management support and the irregular forms data.

In line with interviews, higher importance was given to standardization and adoption barriers. Two aspects argued as the antagonist to each other. The focus group asserted as the level standardization for data-driven technologies increases the barriers will decrease. Analogous to the interviews some human-related innovation challenges were discussed. The laggardness of the built environment was also endorsed for the implementation of the data-driven approach. Nonetheless, cloud-based project management within the BIM department was revealed to be implemented. The common data environment denotes the real-time information sharing and usage by the project teams. Lastly, the biggest challenge identified as the unstructured form of data obtained from different sources in different formats. In the end, the transition aspect was found as the key determinant while exploring the nature of projects and the effects on the management. As a conclusion, innovation steps, standardization of the technology, and implementation challenges (Table 12) were discovered widely for the transition component of projects.

Table 12: Data-Driven Technologies in the Transition Aspect

Transition (Technology) Aspect	**Innovation Steps**	• Adapting slow comparing to other industries • Step-wise approach at Ballast Nedam • Creating structured data - the initial innovation step • Implementing ISO 19650 into the whole company
	Standardization	• Benefiting from cloud-based platforms • Using the common data environment (CDE) • Creating structured project data, and using the information as standards for all projects • Applying contractual agreements as shared knowledge
	Adoption Barriers	• High speed of technological growth • Convincing people • Lack of trained personnel • Management support • Unstructured form of data • Unique nature of projects

7.2 Answering the Research Questions

Sub-RQ2: What are the components of projects and their relation to project management practices?

As far as one of the sub-objective concerns, it was aimed to explore the setting of projects and how different components of projects are inter-related by different project management exercises. A traditional literature review was undertaken in order to answer the question above. The project management literature was scattered in the data-driven technology context. For this reason, the *4-T Framework* was identified to explore projects' nature. Furthermore, the results of the review arranged according to the framework and these *are time, team, task*, and *transition*. Moreover, the fourth aspect, transition, addressed the technological perspectives which are investigated as the data-driven approach in the thesis. Thus, the transition component of the project is aimed to link the gap between project management practices and data-driven technologies. This formation allowed the researcher to define how projects are comprised and the situation of data-powered practices, which was identified as the research gap.

Findings on the time aspect pointed out the *value managemen*t perspective. Regarding the team, *project teams* and *project governance mechanisms* were found commonly in the literature. The task aspect was determined by the *project performance* and *project phases*. *Data-driven technologies* and *implementation* were categorized under the transition aspect of the framework. These findings explain the management practices for different project components.

In this way, the literature review provided a baseline to comprehend the project nature and key management components by linking them with knowledge of the data-driven approach. Although the components and management concepts identified separately, it was revealed that they are connected as proposed by Lundin & Söderholm (1995). Therefore, they should be examined together when discovering the project management practices. As a result, the answer to the first assisting question can be summarized as follows: *Projects consist of time, team, task, and transition aspects where each of the components requires a different management approach.*

Based on the given answer, the framework provides different management purposes. These purposes identified by the literature also assisted in preparing for the interviews. Thus, it did not only answer the sub-research question but also constituted the foundation of the sequential analysis.

Sub-RQ1: What are the current data-driven project management trends and applications in the built environment?

The second sub-research question targeted to understand the status quo of the data-driven approach for different project purposes in the built environment. It was done by conducting desk research within the case company. For this purpose, company documents, archival records, employee portals, department presentations, and BIM procedures were analyzed. The analysis described the emerging digital trends, industry-wise standards, project phases within the Netherlands, the BIM theme, and different management purposes based on cloud technologies.

As a result of the desk-based research, digital trends were identified including virtual buildings, digitalization of workflows, integrated management platform, data preparation software and information delivery. At the same time, to implement or use these innovations properly international and industry-specific standards were described. Standards by buildingSMART and ISO 19650 were introduced. Following this, the BIM environment was identified. It aimed to demonstrate the BIM concept is not only capable of design but also for integrating various kinds of project data, like time and cost.

Project phases at Ballast Nedam and in the Netherlands were identified. The reason to introduce phases was to justify the research scope. It was defined for the execution and monitoring & controlling phase in Chapter 1. The current situation of the data-driven practices also introduced by cloud-based platforms and different management purposes to use common project information. These purposes include but not limited to document management, coordination and collaboration, data analytics, cost, and field management.

Lastly, the software pool established in the company was identified. It revealed there were many programs used by the project teams, thus it brings a need to communicate those different outputs. Therefore, the technological ecosystem was identified in order to give a complete outlook of the company and industry in general. As a result, the answer to the research question can be listed as follows*:*

- *The major trends are virtual buildings and digitalization of information delivery*.
- *The standards are promoting the use of data-driven innovations.*
- *The BIM environment brings opportunities for leveraging data when combined with cloud-based platforms.*
- *Cloud technologies are developing and providing a common workplace with different project management purposes.*

Sub-RQ3: How are the project components important while adopting data-driven methods to manage projects?

The third sub-research question aimed to address different project components while adopting data-powered management applications. For this purpose, interviews and a focus group discussion were used. According to the collective results for each project feature, several findings came forward. These findings helped to answer the research question.

Even though the importance of results is separate for project components (time, team, task, and transition) most of the findings were found inter-related. The prominent time-based component was historical data. Regarding the team, contract type, team learning, and internal/external procedures were found influential on project management. For the task component, task definition was explored as the main management purpose. Lastly, transition, defined as the data-driven technology, emphasized on standardization and barriers to adoption.

Given the findings for each project component, the answer for the third assisting questions can be formulated as follows:

- *The time aspect is important for project values (time/cost) and historical data usage in future projects. It sets the baseline for creating and using project data.*

- *Team component, as for the whole construction, shapes around the contract type and a determinant factor the project execution. The information generated in teams is essential for creating a database for learning.*

- *Task definitions come with contracts. Role and data requirements are important factors of project governance and project performance while implementing data-related technologies.*

- *Transition is the phase where organizations start changing. Standardization of data-driven processes as well as being aware of challenges can help companies to transform. Thus, the implementation strategy is a key factor while managing change and adopting the data-driven project approach.*

In conclusion, two research goals, *''understanding the current state of data-driven applications* and *exploring the gains of data-powered project management systems in the construction industry by linking with project components''* were accomplished. As a result, overall findings from the sub-research questions can help to answer the main research question below.

Main RQ: How can data-driven technologies enable construction project management practices?

Projects comprise of different components. Each component brings varying management needs. Therefore, when investigating the project management exercises time, team, task, and transition aspects are identified and under those components, different management mechanisms are explored. The data-driven approach is integrated into the transition aspect. However, other project components are also discovered in the data context. As the outcome of the research, the answers to the main research question had been formulated as propositions. By exploring the links between project components and the data-driven approach, the findings of the thesis suggest promising future research inquiries. Thus, as the findings indicate and in light of the answers of sub-research questions, data-driven applications can contribute to project management exercises with the following propositions:

P1. *The more historical data used in construction projects, the fewer the cost and time overruns.*

> Historical data means using past project knowledge into future projects. It can contribute to daily data recording and construction progress tracking, known as field management. Therefore, the benefits it brings can be measured by time and cost.

P2. *Creating a project database and defining information requirements are determinants for the standardization of the data-driven workflows.*

> The data and information conditions residing in contracts can bring a common understanding among the project partners. Data-driven tools can also help to structure the discrepancies in models, documents, and execution specifications which can contribute to document management.

P3. *The storage and accessibility of the project information with cloud applications determine the interaction among the project participants.*

> Cloud-based technologies increase the accessibility of data, promotes the data exchange, make information delivery easier, and encourage collaboration among the team member. A common data environment can be used to manage stakeholders where each project participant can work simultaneously. It can contribute to project scheduling, making time entries, generating data-supported reports, real-time design collaboration with different modules.

P4. *The more the standardization level of data-related technologies is, the fewer the barriers are for implementation.*

> Data-driven standards in the built environment can lead the way and promote the adoption of technology. Companies can benefit from data-powered tools by creating structured data and standardize their workflows.

7.3 Academic and Practical Contributions

Academic Contributions

This research has been conducted in order to clarify the data-driven project management approach in the built environment by focusing on different project components. In fact, the thesis fills the knowledge gap about the applicability of the data-driven approach to the components of projects and their reflection on project management purposes.

First, the research builds upon the work of Lundin and Söderholm (1995), where project aspects are identified as time, team, task and transition. It explains different components of projects and the relation between them. Varying management purposes was investigated under the framework. Thus, it can be considered as a building block towards project management practices on their relationship with the project nature.

Second, the research contributes to the understanding of the management of construction projects, specifically for execution and monitoring phases (Maskuriy et al., 2019). Data-driven applications were discovered with their intended uses by including a main contractor in the Netherlands into the research. Thus, it helps scholars to deduce how construction companies structure their project management workflows and manage projects while implementing algorithmic tools. Specifically, it sheds light on contractual agreements (Marzouk & Enaba, 2019), historical data use for future projects (Zhong et al., 2019) and standards like common data environment. Moreover, this research also addresses the adoption barriers in the built environment which directly influence the implementation of data-driven technologies. Particularly, it draws attention that challenges require changes (Whyte et al., 2016) regarding data structuring, convincing people and standardization of business processes.

Lastly, since the data-driven technologies are highly technical and related to other domains, such as computer science and data analytics, most of the contributions in the existing literature are based on theoretical foundations (Loyola, 2018). For this reason, the current literature lacks applications of those technologies into projects or construction project management. Thus, this research fills the gap by exploring the nature of projects and linking those into different data empowered management objectives. The thesis provides providences on what components projects are consist of, how the nature of the projects affects the project management outcome and what are the opportunities and challenges when implementing the data-driven approach.

Practical Contributions

This thesis also has managerial implications. It provides guidelines for managers in the construction sector who engage with data-driven tools in projects.

Findings indicated several implications regarding the implementation process of data-driven technologies. As identified in this thesis, innovations are demanding and time-consuming to adopt into the organizations. Among the adoption barrier, the human-factor became prominent where convincing people, training level of the employees and having C-level management support found as the main challenges of implementation. Accordingly, managers need to react to those people-centric issues and be planned for solutions.

Similarly, as opposite the challenges, standardization of workflow can help managers to define and structure project management practices. However, standardization and fully embracing the new technologies require radical changes. During the implementation journey, unexpected results may come to the surface. Thus, the change itself is continuous. In line with this, first managers may consider the structure the way they manage the changes and apply the procedures accordingly to the new circumstances. Therefore, change management and configuration management (Whyte et al., 2016) stances may lead the way for managers to initiate and shape their implementation strategies.

7.4 Limitations of the Research

Like any other scientific research, this thesis has also a few limitations regarding the chosen framework, research methods and applications of those methods. They can be listed as follows:

The first limitation of this research comes from the chosen theoretical framework. Even though the model is generally applicable to project management practices (Sydow & Braun, 2018), it lacks the inter-organizational dimension. Bakker, (2010) proposed an updated framework in which the transition component is replaced by context. He backed his theory after analyzing 15 years of literature where there were not many studies on the transition aspect. However, the framework was applied for one company thus, the inter-organizational perspective did not take into consideration.

Secondly, the research method chosen is a single-case study with cross-sectional settings. It means the analysis is done to obtain a snapshot of the situation in a defined period. Thus the results listed and the relationship between them may vary in time. In addition, in term of single-case study, findings may be different and comparable if it was designed with multiple cases. But, since the thesis study is limited in time and the objective is to explore a phenomenon these strategies are chosen.

The third limitation comes with the focus group. Kitzinger (1995) suggests that the ideal size of a focus is between four and eight. Also, mini-focus groups are now getting attention with three participants. Yet, in this thesis given the Corona outbreak, and the availability of division managers, the focus group only included two participants. This situation limits the method by hampering the generation and sprout of different ideas. What is more, due to the pandemic we have been facing, the focus group and interviews were conducted via conference calls. Thus, compared to face-to-face interactions, personal impressions and gestures could have been captured better.

The fourth limitation may be observed with the interview responses. Participants may have felt they are a part of a research, consequently, their answers may have been hampered by the questions and given inaccurately. Response bias situation, in this case, may conceal the negative sides of the research topic to be revealed. However, to minimize the response bias effect the question orders were organized carefully and questions about the challenges were directed to interviewees. The participants were also informed that the information they provided will be used anonymously.

Lastly, the generalizability of the findings can be explained by external validity. It means the results may not apply to all construction companies in the Netherlands, which in turn comes as a limitation of any case-study. In conclusion, even though the results provide rich insights on the current situation, the research lacks generalization due to the qualitative nature of the study.

7.5 Future Research Avenues

Based on the given limitations in the previous section, several future research avenues can be drawn. First, the reflection of the 4-T Framework can be updated by including the inter-organizational interactions. This recommendation also addresses that multiple case studies can be investigated. However, as the transition was treated as the technology, changing one framework component may also affect the applicability of the theory.

Second, as research conducted at one point in time, it can further be investigated with a longitudinal method. Observation of the data-driven project application over time may provide richer insights and it can reveal how the adoption process is evolving in the built environment. Since the growth rate of the technology is quite high, a wider time horizon with a comparison of different periods may explore analogies.

Third, as mentioned in limitations, the focus group can be designed with more participants. Wider populations enable the cross-fertilization of ideas and may give richer insights. What is more, if the time limit of the study allows, more than one group may also be designed. Because, regardless of the size of the focus group, participants may be imposed biases while expressing their opinions. Thus, conducting a series of group discussion reduces personal biases and is also more generalizable.

Fourth, the results printed out by this thesis are not statistically validated, only the mentioned frequency of word was presented. Therefore, it is a drawback of qualitative studies. Besides, conducting interviews with more participants and adding a quantitive method, such as surveys, into the study may strengthen the generalizability of findings. In this way, while the explorative objective is ensured, the reliability of the research will also increase.

Lastly, another useful advice can be given regarding the interview participants. Participants from two different departments (Desing & Engineering and Site-Engineering) were chosen. This selection justified as their relevance to data-driven project techniques. However, other expertise, such as procurement and finance, can also be investigated in future studies. This may provide an in-depth understanding of the differences among the professions and give valuable insights on how the use of the data-powered can be integrated.

7.6 Reflection

During the thesis, I realized it was an iterative process where each chapter yields inputs for the next one. After an extensive literature review, the rationale to answer research questions were roughly shaped. However, while conducting different methods it was difficult to foresee what would be the next direction and how could the conclusion. Throughout the research journey, some significant points have been identified to reflect upon. Therefore, here, the researcher lists key reflection points:

1. *Personal Interaction:* The thesis started just after Corona measures have been applied. For this reason, all of the meetings with both internal and external supervisors took place virtually. In addition to that, the data collection process (interviews and focus group) was also carried out remotely. Therefore, I would be better motivated and collect more interactive results. However, our health, as well as others', are of high importance and it was an extraordinary situation to experience.

2. *Witnessing Different Opinions*: During the interviews, 12 people participated who posses different job titles. Although it is expected to obtain different opinions from participants, some surprising answer was given. For example, it was highly insightful to realize how different site-engineers interpret the situation than a commercial manager. Given the chance, I would include more participants with varying professions.

3. *Defining Research Boundaries:* As the scope of the thesis is extensive, a demarcation could have been done. Data-driven technologies explored for project management purposes. Some of the purposes identified as historical data usage, data structuring, document management, and implementing cloud-based information communication. For example, the scope would be narrowed into the data generation and historical data in projects. This would provide in-depth results of a specific data-powered project exercise.

References

Agarwal, B. R., Chandrasekaran, S., & Sridhar, M. (2018). *Imagining construction ' s digital future*. (Exhibit 1), 1–28.

Ahmed, V., Aziz, Z., Tezel, A., & Riaz, Z. (2018). Challenges and drivers for data mining in the AEC sector. *Engineering, Construction and Architectural Management*, *25*(11), 1436–1453. https://doi.org/10.1108/ECAM-01-2018-0035

Ahmed, V., Tezel, A., Aziz, Z., & Sibley, M. (2017). The future of Big Data in facilities management: opportunities and challenges. *Facilities*, *35*(13–14), 725–745. https://doi.org/10.1108/F-06-2016-0064

Autodesk.com. (n.d.). Explore Construction Management Software: Autodesk BIM 360. Retrieved April 24, 2020, from https://www.autodesk.com/bim-360/explore/

As, I., Pal, S., & Basu, P. (2018). Artificial intelligence in architecture: Generating conceptual design via deep learning. *International Journal of Architectural Computing*, *16*(4), 306–327. https://doi.org/10.1177/1478077118800982

Bakker, R. M. (2010). Taking Stock of Temporary Organizational Forms: A Systematic Review and Research Agenda. *International Journal of Management Reviews*, *12*(4), 466–486. https://doi.org/10.1111/j.1468-2370.2010.00281.x

Ballast Nedam. (2018). Informatie Management Afbeeldingen.

Ballast Nedam. (2019). About Us. Retrieved from https://www.ballast-nedam.com/

Ballast Nedam. (2019). Business Plan 19: Building Design and Engineering.

Ballast Nedam. (2019). Business Plan: CSR Policy and Targets 2020-2022.

Ballast Nedam. (2019). Digital Construction Management: Roadmap.

Barton, D., & Court, D. (2012). Making advanced analytics work for you. *Harvard Business Review*, *90*(10), 78–83.

Bilal, M., Oyedele, L. O., Kusimo, H. O., Owolabi, H. A., Akanbi, L. A., Ajayi, A. O., … Davila Delgado, J. M. (2019). Investigating profitability performance of construction projects using big data: A project analytics approach. *Journal of Building Engineering*, *26*(February), 100850. https://doi.org/10.1016/j.jobe.2019.100850

Bilal, M., Oyedele, L. O., Qadir, J., Munir, K., Ajayi, S. O., Akinade, O. O., … Pasha, M. (2016). Big Data in the construction industry: A review of present status, opportunities, and future trends. *Advanced Engineering Informatics*, *30*(3), 500–521. https://doi.org/10.1016/j.aei.2016.07.001

Bjorvatn, T., & Wald, A. (2018). Project complexity and team-level absorptive capacity as drivers of project management performance. *International Journal of Project Management*, *36*(6), 876–888. https://doi.org/10.1016/j.ijproman.2018.05.003

Boyd, D., & Crawford, K. (2011). Six provocations for big data. *A Decade in Internet Time: Symposium on the Dynamics of the Internet and Society*, *21*. Oxford Internet Institute

Oxford, UK.

Bryde, D., Broquetas, M., & Volm, J. M. (2013). The project benefits of building information modelling (BIM). *International Journal of Project Management*, *31*(7), 971–980. https://doi.org/10.1016/j.ijproman.2012.12.001

Bryde, D., Unterhitzenberger, C., & Joby, R. (2018). Conditions of success for earned value analysis in projects. *International Journal of Project Management*, *36*(3), 474–484. https://doi.org/10.1016/j.ijproman.2017.12.002

BuildingSMART.org. (2019). Standards. Retrieved from: https://www.buildingsmart.org/standards/bsi-standards/

Burak Gunay, H., Shen, W., & Newsham, G. (2019). Data analytics to improve building performance: A critical review. *Automation in Construction*, *97*(June 2018), 96–109. https://doi.org/10.1016/j.autcon.2018.10.020

Chen, M., Mao, S., & Liu, Y. (2014). Big data: A survey. *Mobile Networks and Applications*, *19*(2), 171–209. https://doi.org/10.1007/s11036-013-0489-0

de Andrade, P. A., Martens, A., & Vanhoucke, M. (2019). Using real project schedule data to compare earned schedule and earned duration management project time forecasting capabilities. *Automation in Construction*, *99*(October 2018), 68–78. https://doi.org/10.1016/j.autcon.2018.11.030

Delisle, J. (2019). Uncovering temporal underpinnings of project management standards. *International Journal of Project Management*, *37*(8), 968–978. https://doi.org/10.1016/j.ijproman.2019.09.005

Derakhshan, R., Turner, R., & Mancini, M. (2019). Project governance and stakeholders: a literature review. *International Journal of Project Management*, *37*(1), 98–116. https://doi.org/10.1016/j.ijproman.2018.10.007

Farghaly, K., Abanda, H., Vidalakis, C., & Wood, G. (2017). *BIM Big Data System Architecture for Asset Management: A Conceptual Framework*. (July), 289–296. https://doi.org/10.24928/jc3-2017/0163

Fuentes, M., Smyth, H., & Davies, A. (2019). Co-creation of value outcomes: A client perspective on service provision in projects. *International Journal of Project Management*, *37*(5), 696–715. https://doi.org/10.1016/j.ijproman.2019.01.003

Gandomi, A., & Haider, M. (2015). Beyond the hype: Big data concepts, methods, and analytics. *International Journal of Information Management*, *35*(2), 137–144. https://doi.org/10.1016/j.ijinfomgt.2014.10.007

Green, S. D., & Sergeeva, N. (2019). Value creation in projects: Towards a narrative perspective. *International Journal of Project Management*, *37*(5), 636–651. https://doi.org/10.1016/j.ijproman.2018.12.004

Han, K. K., & Golparvar-Fard, M. (2017). Potential of big visual data and building information modeling for construction performance analytics: An exploratory study. *Automation in Construction*, *73*, 184–198. https://doi.org/10.1016/j.autcon.2016.11.004

Hanna, A. S., Tadt, E. J., & Whited, G. C. (2012). Request for information: Benchmarks and metrics for major highway projects. *Journal of Construction Engineering and Management*, *138*(12), 1347–1352. https://doi.org/10.1061/(ASCE)CO.1943-

7862.0000554

Higgins, A. (2018, February). How One Old-Timer Learned to Embrace Construction Data and Machine Learning. Retrieved from https://connect.bim360.autodesk.com/embracingconstruction-data

Hodgson, D., & Cicmil, S. (2007). The politics of standards in modern management: Making "the project" a reality. *Journal of Management Studies*, *44*(3), 431–450. https://doi.org/10.1111/j.1467-6486.2007.00680.x

Ismail, S. A., Bandi, S., & Maaz, Z. N. (2018). An Appraisal into the Potential Application of Big Data in the Construction Industry. *International Journal of Built Environment and Sustainability*, *5*(2), 145–154. https://doi.org/10.11113/ijbes.v5.n2.274

ISO, B. (2018). 19650-1: 2018. BSI Standards Publication Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM)- Information management using building information modelling.

Jin, X., Wah, B. W., Cheng, X., & Wang, Y. (2015). Significance and Challenges of Big Data Research. *Big Data Research*, *2*(2), 59–64. https://doi.org/10.1016/j.bdr.2015.01.006

Kim, C. W., Yoo, W. S., Lim, H., Yu, I., Cho, H., & Kang, K. I. (2018). Early-warning performance monitoring system (EPMS) using the business information of a project. *International Journal of Project Management*, *36*(5), 730–743. https://doi.org/10.1016/j.ijproman.2018.03.010

Kitzinger, J. (1995). Qualitative Research: Introducing focus groups. *BMJ*, *311*(7000), 299 LP – 302. https://doi.org/10.1136/bmj.311.7000.299

Kreiner, K. (1995). In Search of Relevance: Project Management in Drifting Environments. *Scandinavian Journal of Management*, *11*(4), 335–346.

Kusimo, H., Oyedele, L., Akinade, O., Oyedele, A., Abioye, S., Agboola, A., & Mohammed-Yakub, N. (2019). Optimisation of resource management in construction projects: a big data approach. *World Journal of Science, Technology and Sustainable Development*, *16*(2), 82–93. https://doi.org/10.1108/wjstsd-05-2018-0044

Laney, D. (2001). *3D data management: controlling data volume, velocity, and variety. Application Delivery Strategies File 949, META Group Inc., Stamford*.

Laursen, M., & Svejvig, P. (2016). Taking stock of project value creation: A structured literature review with future directions for research and practice. *International Journal of Project Management*, *34*(4), 736–747. https://doi.org/https://doi.org/10.1016/j.ijproman.2015.06.007

LaValle, S., Lesser, E., Shockley, R., Hopkins, M. S., & Kruschwitz, N. (2011). Big data, analytics and the path from insights to value. *MIT Sloan Management Review*, *52*(2), 21–32.

Levitt, R. E. (2011). Towards project management 2.0. *Engineering Project Organization Journal*, *1*(3), 197–210. https://doi.org/10.1080/21573727.2011.609558

Loyola, M. (2018). Big data in building design: A review. *Journal of Information Technology in Construction*, *23*(October 2017), 259–284.

Lu, P., Cai, X., Wei, Z., Song, Y., & Wu, J. (2019). Quality management practices and inter-organizational project performance: Moderating effect of governance mechanisms. *International Journal of Project Management*, *37*(6), 855–869. https://doi.org/10.1016/j.ijproman.2019.05.005

Lundin, R. A., & Söderholm, A. (1995). A theory of the temporary organization. *Scandinavian Journal of Management*, *11*(4), 437–455. https://doi.org/10.1016/0956-5221(95)00036-U

Marzouk, M., & Enaba, M. (2019). Text analytics to analyze and monitor construction project contract and correspondence. *Automation in Construction*, *98*(November 2018), 265–274. https://doi.org/10.1016/j.autcon.2018.11.018

Maskuriy, Selamat, Maresova, Krejcar, & Olalekan. (2019). Industry 4.0 for the Construction Industry: Review of Management Perspective. *Economies*, *7*(3), 68. https://doi.org/10.3390/economies7030068

Matinheikki, J., Artto, K., Peltokorpi, A., & Rajala, R. (2016). Managing inter-organizational networks for value creation in the front-end of projects. *International Journal of Project Management*, *34*(7), 1226–1241. https://doi.org/https://doi.org/10.1016/j.ijproman.2016.06.003

Mcafee, A., & Brynjolfsson, E. (2012). HBR. ORG Spotlight on Big Data Big Data: The Management Revolution. *Harv. Bus. Rev*, 3–9.

Mesa, H. A., Molenaar, K. R., & Alarcón, L. F. (2019). Comparative analysis between integrated project delivery and lean project delivery. *International Journal of Project Management*, *37*(3), 395–409. https://doi.org/10.1016/j.ijproman.2019.01.012

Miles, M. B. and Huberman, A.M. (1994) Qualitative Data Analysis (2nd ed.). Thousand Oaks, CA: SAGE.

Müller-Seitz, G., & Sydow, J. (2011). Terminating institutionalized termination: Why SEMATECH became more than a temporary system. In *Advances in Strategic Management* (Vol. 28). https://doi.org/10.1108/S0742-3322(2011)0000028010

Müller, R., Turner, J. R., Andersen, E. S., Shao, J., & Kvalnes, Ø. (2016). Governance and Ethics in Temporary Organizations: The Mediating Role of Corporate Governance. *Project Management Journal*, *47*(6), 7–23. https://doi.org/10.1177/875697281604700602

Oraee, M., Hosseini, M. R., Papadonikolaki, E., Palliyaguru, R., & Arashpour, M. (2017). Collaboration in BIM-based construction networks: A bibliometric-qualitative literature review. *International Journal of Project Management*, *35*(7), 1288–1301. https://doi.org/10.1016/j.ijproman.2017.07.001

Papadonikolaki, E., van Oel, C., & Kagioglou, M. (2019). Organising and Managing boundaries: A structurational view of collaboration with Building Information Modelling (BIM). *International Journal of Project Management*, *37*(3), 378–394. https://doi.org/10.1016/j.ijproman.2019.01.010

Pargar, F., Kujala, J., Aaltonen, K., & Ruutu, S. (2019). Value creation dynamics in a project alliance. *International Journal of Project Management*, *37*(5), 716–730. https://doi.org/10.1016/j.ijproman.2018.12.006

PMI, 2009. Practice Standard for Project Risk Management. Project Management Institute, Newton Square, PA.

PMI's Pulse of the Profession, 2016. Delivering Value – Focus on Benefits During Project Execution. Project Management Institute, Newtown Square, PA: USA.

Project Management Institute. (2017). *A guide to the project management body of knowledge (PMBOK guide)* (Vol. 6). Project Management Inst.

Riis, E., Hellström, M. M., & Wikström, K. (2019). Governance of Projects: Generating value by linking projects with their permanent organisation. *International Journal of Project Management*, *37*(5), 652–667. https://doi.org/10.1016/j.ijproman.2019.01.005

Sekaran, U., & Bougie, R. (2016). *Research methods for business: A skill building approach.* John Wiley & Sons.

Scheffer, M., Mattern, H., & König, M. (2018). BIM Project Management. In A. Borrmann, M. König, C. Koch, & J. Beetz (Eds.), *Building Information Modeling: Technology Foundations and Industry Practice* (pp. 235–249). https://doi.org/10.1007/978-3-319-92862-3_13

Sirisomboonsuk, P., Gu, V. C., Cao, R. Q., & Burns, J. R. (2018). Relationships between project governance and information technology governance and their impact on project performance. *International Journal of Project Management, 36*(2), 287–300. https://doi.org/10.1016/j.ijproman.2017.10.003

Söderlund, J. (2004). Building theories of project management: Past research, questions for the future. *International Journal of Project Management*, *22*(3), 183–191. https://doi.org/10.1016/S0263-7863(03)00070-X

Svejvig, P., & Andersen, P. (2015). Rethinking project management: A structured literature review with a critical look at the brave new world. *International Journal of Project Management*, *33*(2), 278–290. https://doi.org/10.1016/j.ijproman.2014.06.004

Sydow, J., & Braun, T. (2018). Projects as temporary organizations: An agenda for further theorizing the interorganizational dimension. *International Journal of Project Management*, *36*(1), 4–11. https://doi.org/10.1016/j.ijproman.2017.04.012

Takagi, N., & Varajão, J. (2019). Integration of success management into project management guides and methodologies - position paper. *Procedia Computer Science, 164,* 366–372. https://doi.org/10.1016/j.procs.2019.12.195

Taylan, O., Kabli, M. R., Porcel, C., & Herrera-Viedma, E. (2018). Contractor Selection for Construction Projects Using Consensus Tools and Big Data. *International Journal of Fuzzy Systems*, *20*(4), 1267–1281. https://doi.org/10.1007/s40815-017-0312-3

The New Zealand BIM Handbook. (2019). A Guide to Enabling BIM on Built Assets. Third Edition. ISBN 978-0-473-47832-2

Turner, J. R., & Müller, R. (2003). On the nature of the project as a temporary organization. *International Journal of Project Management*, *21*(1), 1–8. https://doi.org/10.1016/S0263-7863(02)00020-0

Vanhoucke, M. (2011). Measuring Time: Earned value or earned schedule? Retrieved from http://www.pmknowledgecenter.com/dynamic_scheduling/control/measuring-time-earnedvalue-or-earned-schedule

Venugopal, M. (2020, April). How to Connect Your Project Data with Business Intelligence. Retrieved from https://connect.bim360.autodesk.com/project-data-business-intelligence

Viktor, M.-S., & Cukier, K. (2013). *Big data: A revolution that will transform how we live, and think*. Houghton Mifflin Harcourt.

Whyte, J., Stasis, A., & Lindkvist, C. (2016). Managing change in the delivery of complex projects: Configuration management, asset information and “big data.” *International Journal of Project Management*, *34*(2), 339–351. https://doi.org/10.1016/j.ijproman.2015.02.006

Woodhead, R., Stephenson, P., & Morrey, D. (2018). Digital construction: From point solutions to IoT ecosystem. *Automation in Construction*, *93*(March), 35–46. https://doi.org/10.1016/j.autcon.2018.05.004

Yin, R. K., & Campbell, D. T. (2018). Case study research and applications: Design and methods.

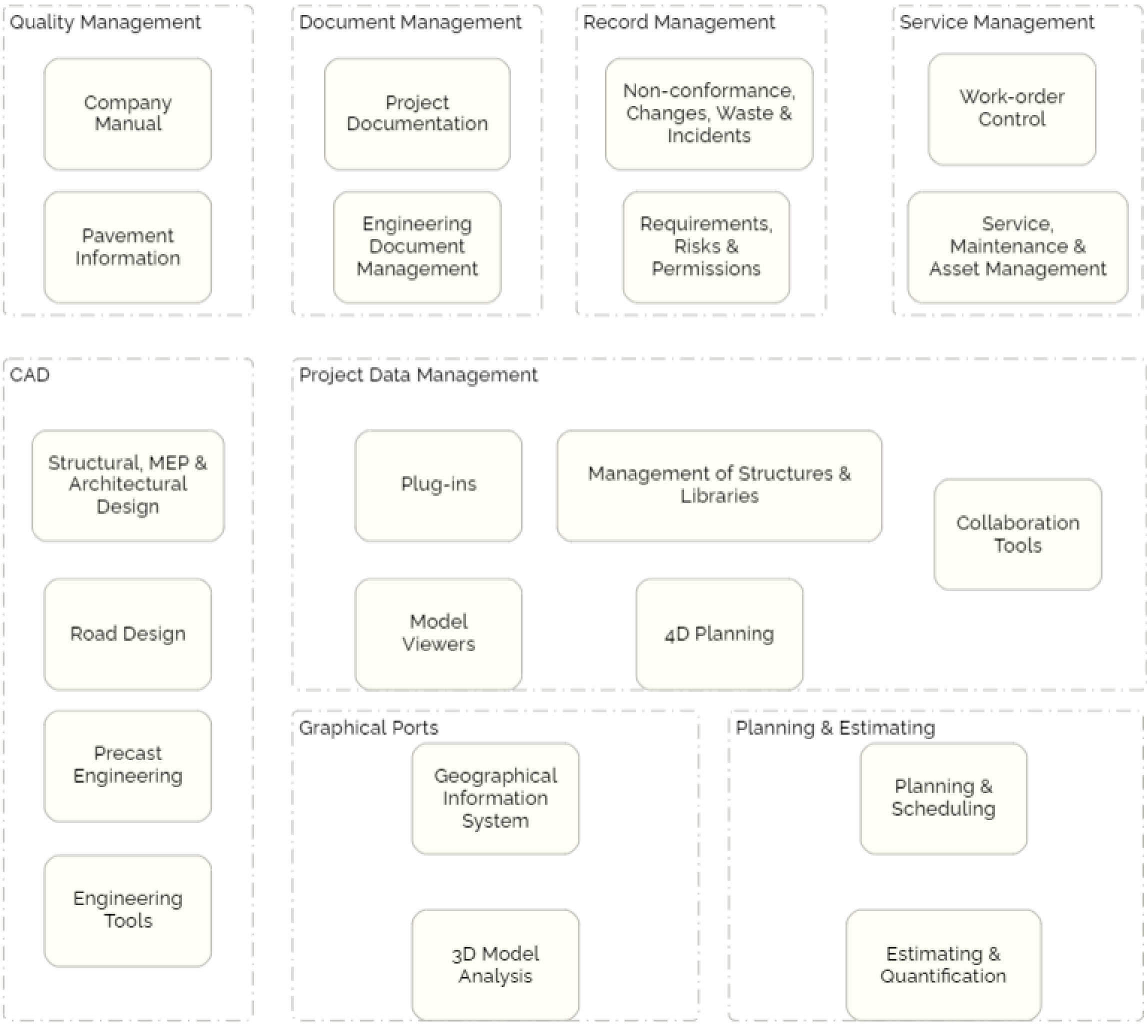
Zhang, F., Fleyeh, H., Wang, X., & Lu, M. (2019). Construction site accident analysis using text mining and natural language processing techniques. *Automation in Construction*, *99*(December 2018), 238–248. https://doi.org/10.1016/j.autcon.2018.12.016

Zhong, B., Wu, H., Ding, L., Love, P. E. D., Li, H., Luo, H., & Jiao, L. (2019). Mapping computer vision research in construction: Developments, knowledge gaps and implications for research. *Automation in Construction*, *107*(April), 102919. https://doi.org/10.1016/j.autcon.2019.102919

Zwikael, O., Chih, Y. Y., & Meredith, J. R. (2018). Project benefit management: Setting effective target benefits. *International Journal of Project Management*, *36*(4), 650–658. https://doi.org/10.1016/j.ijproman.2018.01.002

Appendices

Appendix A: The Software Pool



Appendix B: The Interview Protocol

Interview Protocol

Opening	
Researcher and Participants introduce themselves	**Could you describe your role at Ballast Nedam?**
Presentation of Informed Consent & Recording Procedure	
Presentation of the current situation	
Presentation of the goal of the study	

	Questions	Topics to be addressed
No.	**Questions about Project Management**	
1	How do you evaluate performance and project success/failure? (What do you find valuable?)	Project Performance (Time and Task Aspect)
2	How do you define the benefits obtained from a project?	Project Performance
3	How do you decide/execute the project stages during the construction?	Project Phases
4	How do you apply time, team, task and technology constraint in a project?	Overall Framework evidence
5	How do you ensure sufficient coordination among the project participants?	Project Teams
Questions about Data-Driven Applications (The Transition Aspect)		
6	What kinds of data sources are you dealing with?	Data Evidence
7	How do you combine the data generated from different sources?	Data Capture
8	How do you find using (historical) data in order to improve future projects?	Data Interpretation
9	How do you manage the discrepancy between models, exports and publishment of those different models?	Changing Scope/Rework
General Questions for DDPM		
10	How do you think it is important for project teams to make an inventory of what is going on on-site applications?	Progress Tracking
11	What are the themes and objectives that you are working on for the near future (5 years)?	Trends in Built Environment
12	How do you see the benefits of using supportive equipment on-site for data capture?	Progress Tracking
Insights		
14	What do you believe are the major assets of leveraging data? Major weaknesses?	Future directions

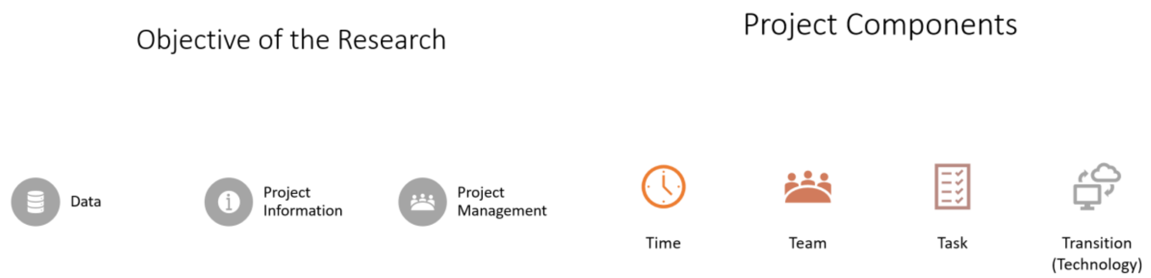
Closing
Did we miss to emphasize any topics that you think might be important?
Thank you for all that valuable information, is there anything else you'd like to add before we end?

Appendix C: Information Sheet For Interviews

Information Sheet

Description and Purpose of the Study

With the increasing amounts of data generated from various sources companies now are aware of the term big data more than ever. In the built environment where large projects are handed over, this data disturbance also needs to be managed properly. Construction is a field in which building or infrastructural works are delivered as an end-product and these projects are complex in nature thus require multiple ways of project management practices. The study will aim, in general, to explore the current state and future uses of big data and its enabling technologies in the construction domain by following the project management guidelines. The findings of this study will aim to help construction managers and researchers to develop a body of knowledge of data-driven construction management. This research project is part of a master thesis, in partial fulfillment of the requirements for the degree of Master of Science in Management of Technology, at the TU Delft.



Participant rights

Participants can refuse to answer questions and can withdraw from the study at any time, by notifying the researcher, without having to give a reason. Participants have the right to request access to any personal data collected. Complaints can be filed by contacting the data protection officer of the TU Delft.

Processing of Personal Information

The interviews will be audio-recorded and transcribed to meet scientific standards. The data will be stored. Any personal data, including audio recording, is destroyed once the research has been completed. Personal information collected that can identify a participant, such as name or where the participant works, will not be shared beyond the study team. Information gathered during the interviews can be used for the researcher's master thesis, through anonymized quotes.

Contact Details

- Researcher: Yildiray Ocalan
- Telephone: 0682931226
- E-mail: n.y.ocalan@student.tudelft.nl
- Research Institute Information: Delft University of Technology, privacy-tud@tudelft.nl
- Affiliated company: Ballast Nedam

Sources Adopted: *TU Delft | GDPR Informed Consent and data storage. (2018). Retrieved May 24, 2020, from https://www.tudelft.nl/en/about-tu-delft/strategy/integrity-policy/human-research-ethics/template-informed-consent-form/*

Appendix D: The Informed Constent Form

Informed Consent Form for Management of Technology

Please tick the appropriate boxes	**Yes**	**No**
Taking part in the study		
I have read and understood the study information, or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	○	○
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	○	○
I understand that taking part in the study involves video and/or audio recordings and I am aware that those will later be transcribed into text/written notes.	○	○
Risks and Benefits associated with participating in the study		
I understand that taking part in the study involves no risks (physical or mental discomfort)	○	○
I understand that this study would contribute both the academia and industry.	○	○
Use of the information in the study		
I understand that information I provide will be used for the analysis by the researcher and the data collected will be accessible to the participants.	○	○
I understand that personal information collected about me that can identify me, such as [e.g. my name], will not be shared beyond the study team.	○	○
I agree that my information can be quoted in research outputs anonymously	○	○
Future use and reuse of the information by others		
I give permission for the interview output that I provide to be archived anonymously in the TU Delft repository so it can be used for future research and learning.	○	○

Signatures

______________________	______________________	________
Name of participant	Signature	Date

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands what they are freely consenting.

Yildiray Ocalan	___________________	________
Researcher name	Signature	Date

Telephone: 0682931226

E-mail: n.y.ocalan@student.tudelft.nl

Research Institute Information: Delft University of Technology, privacy-tud@tudelft.nl

Sources/References: *TU Delft | GDPR Informed Consent and data storage. (2018). Retrieved May 24, 2020, from https://www.tudelft.nl/en/about-tu-delft/strategy/integrity-policy/human-research-ethics/template-informed-consent-form/*