Managing Large-Scale Software Product Development Projects: A Review

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Abstract

Digitalization is a trendy issue in the business development world. It has experienced how vital the need for digitalization is during the Covid-19 pandemic process. Today's world needs digital transformation both to create a systematic data flow and to compete with competitors. Although the main reason behind digital transformation is to be able to compete because it helps businesses respond more effectively to the customer needs.

Software product development differs from the conventional product development, so does the management of the project. In the last century, software development became a complex problem due to the change in customer needs. Thus, it requires different project management approach than traditional project management.

This paper seeks to understand large-scale software development issue in terms of project management manners by reviewing literature. The paper will highlight the studies performed starting from 1992 until 2022. In doing so, the reader will observe the change in this issue over time. The papers are categorized into 5 groups according to their research questions. These groups are (1) project management and monitoring papers that focused on the governance of a project, (2) case study papers that they do not provide universal solutions but assess a specific case, (3) problem solving papers as they try to develop an algorithm to solve a problem during management processes, (4) explanatory/taxonomy papers which explains the terms and conditions of project management concept, and finally (5) literature review papers. To the best of authors' knowledge, the literature lacks a review study which provides an overview of project management of software product development concept that contains all project management frameworks in the literature.

Keywords
Software product development, project management, literature review, large-scale, project

1. Introduction
Business development and innovation are trending concepts in business world. Business development refers to such actions that enterprises take to increase profit, production, sector growth, reaching out new customer segments (Kind and zu Knyphausen-Aufseß, 2007). These might be achieved via process or product development goals. Innovation as a term indicates new idea, methos, device or more generally, something new (Merriam-Webster.com, 2017).

New product and process development approach is a way to succeed business development and innovation concerns of an enterprise. Developing a new product and/or process has its own difficulties such as uncertainty and ambiguity (Brun, Saetre, and Gjelsvik, 2009). Collyer (2000) declared that 75% of all business transformation projects fail. In addition, Peled (2000) stated only 16% IT projects in the United States are completed on time and budget. Standish

Group's Annual CHAOS 2020 report states that 66% of technology projects end in partial or total failure. This statistic is based on the analysis of 50,000 global projects. The report also concludes that even though the large-scale projects tend to face more obstacles or failing altogether, small-scale software projects also fail one in ten times. Large projects are successful less than 10% of the time. (Johnson, 2020).

These statistics displays how hard is the new product and process development projects to handle. For this reason, project management issues need to be investigated in detail. Since digitalization is a vital concern for enterprises to be able to compete with rivals, digital product/software project management becomes an essential topic.

Statistics display that project management is a crucial topic to successfully complete a project on time and on budget. To overcome the obstacles during the development processes various project management frameworks or methodologies are presented in the literature. The two well-known project management approaches are waterfall and scrum. One of these two can be selected based on the needs and environment of the project. Apart from the chosen approach, managing a large-scale software development project can be a complex and challenging task, requiring careful planning, coordination, and execution.

The objective of this study is to review the literature of large-scale software project management concept. Thus, insights for large-scale software development project management are going to be represented and the know-how at this subject is going to be improved for the reader.

The paper is organized as follows. In Section 2, methodology followed during the literature review is stated. In section 3, the data gathered is analyzed and descriptive statistics are presented. Literature review is explained in Section 4. Results are given in Section 5 and finally, the concluding remarks are drawn based on results in Section 6.

2. Data Extraction Method and Data Analysis

As mentioned earlier, examination of large-scale software development project management concept needs to be highlighted because the literature lacks a comprehensive review. For this purpose, the papers from Web of Science (WoS) database starting from 1992 until 2022 are reviewed. Keywords of "digital product development" or "software development", "project management" and "large scale" are searched in title, abstract and keywords of papers. A total of 76 studies found as a result of this query. When the duplicate and irrelevant outputs are removed, 68 papers remained to be examined in detail.

The 68 papers retrieved from WoS are studied carefully and classified into 5 categories. Most of these papers either perform a case study or uses a real-life data. The line graph below displays the number of articles by year shown in Figure 1.
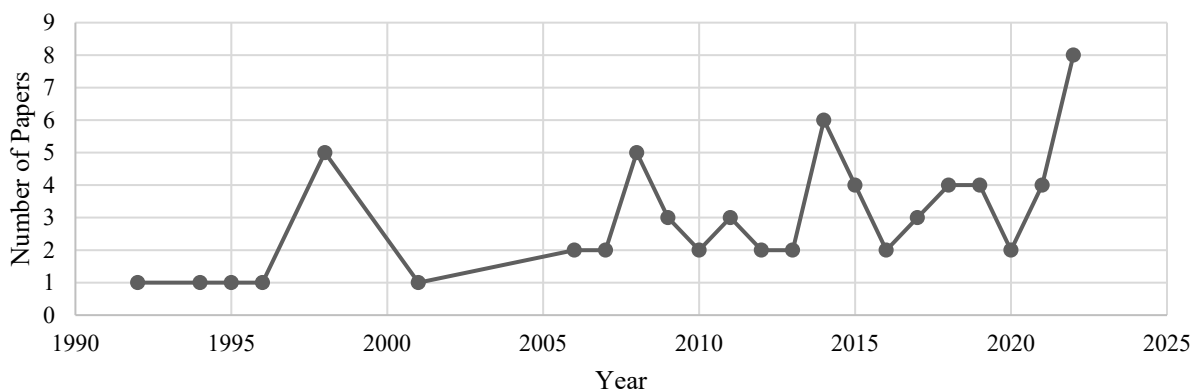

Figure 1. The papers reviewed from 1992 to 2022

Table 1 presents the top 5 sources that has the highest number of publications. Agile Methods: Large-Scale Development, Refactoring, Testing, And Estimation is the top source with 5 papers.

Table 1. The Topmost Article/Paper Publishers

Source Title	Total Number of Paper
Agile Methods: Large-Scale Development, Refactoring, Testing, And Estimation	5
Empirical Software Engineering	3
Information And Software Technology	3
Scientific Programming	2
Journal Of Software-Evolution and Process	2
Information & Management	2

The top 5 papers which cited the most in all databases are displayed in Table2.

Table 2. The Top 5 Most Cited Papers

Article Title	Year	Times Cited
Does Agile work? - A quantitative analysis of agile project success	2015	224
Management of dispersed product development teams: the role of information technologies	1998	124
Exploring software development at the very large-scale: a revelatory case study and research agenda for agile method adaptation	2018	87
Agile requirements prioritization in large-scale outsourced system projects: An empirical study	2013	74
Systematic literature reviews in agile software development: A tertiary study	2017	72

According to their research topic, 68 scientific articles that were reviewed within the context of this study are classified into 5 categories. The categories and the number of articles that these categories contain are given in Table 3.

Table 3. The Categories of Literature Review

Category Name	Number of Papers
Project Management and Monitoring	35
Case Study	15
Problem Solving	7
Explanatory/Taxonomy	6
Literature Review	5
Total	**68**

Nearly the half of these papers aim to determine the status of a project or evaluate an aspect of it such as success rate, effectiveness, time plan, budget etc. 15 papers fall into the case study category. These studies do not provide a universal solution but rather assess a specific case. 7 studies provide a solution approach for a project management problem such as scheduling to minimize the time spent. 6 studies explain a statement or a phenomenon without a case study or literature review. Finally, 5 review articles are presented in the literature.

VOSviewer software is employed the analyze the reviewed papers in terms of the occurrence of the keywords. Figure 2 displays network visualization of reviewed papers and groups these keywords into 6 clusters. (Each color is a cluster.) As shown in the figure, these clusters are closely related with each other. In addition, the size of the labels shows the occurrence density, meaning that keywords such as "team" and "practice" are highly occurring in papers.

Figure 2. Network visualization of reviewed papers

3. Literature Review

The literature was classified under 5 groups, namely, project management and monitoring, case study, problem solving, explanatory/taxonomy and literature review.

3.1 Project Management and Monitoring Based Researches

Project management and monitoring papers that focused on the governance of a project.

An important and prevalent concern is to observe the agile transformation/adoption process within firms and projects. In addition, some papers explained different aspects of agile project management phenomenon. Goh et al. (2013) performed their research about how would agile IS development practices developed in a large-scale IT project. This paper is an outcome of four large-scale IT projects used to construct Beijing Capital International Airport (BCIA) and declares four factors that are critical in these processes, namely: project uncertainty profile and project completion urgency; IT project team capabilities; organizational control mechanisms; and trust relationships among the IT project team, the vendors, and the users. Eklund et al. (2014) stated the challenges while adopting agile practices into mass-produced embedded systems. These challenges are defined based on member companies in a Nordic research partnership with eight international industry companies and three universities. Dyba and Dingsoyr (2015) focused on four principles of agile project management, namely, minimum critical specification, self-managing teams, redundancy, and feedback and learning. These principles stated as a necessity for a successful project management. The application of them was done on Perform project for the Norwegian Public Service Pension Fund. Serrador and Pinto (2015) collected data of 1002 projects from multiple industries and countries via on-line questionnaire and explained the impact of agile on projects' success rates. The analysis showed that there is a positive correlation between the success of a project and the use of agile. Heikkilä et al. (2017) studied on three research questions related to requirements flow in the release management. In-depth study of an Ericsson telecommunications node development organization was carried out. The qualitative analysis display that agile development methods can be successfully adopted in an organization where the higher-level planning processes are not agile. Marinho et al. (2019) performed a survey study. Survey data from 33 countries (263 completed surveys) are gathered to analyze the organizations' agile adoption preference for global software development (GSD). According to this sample, 72% of globally distributed projects employ both agile and traditional approaches ("hybrid"), 25% of GSD uses agile practices, and the rest implements traditional approaches. As a result, it was stated that having a GSD project is not an obstacle to adopt agility. Kovaleva (2020) also surveyed in Russian and global companies to analyze the success of agile projects. Organizations involved in this survey pointed out three success measures of agile transformation, namely, customer/user satisfaction, business value and on-time delivery. Jan et al. (2021) aimed to list the priority-based taxonomy of motivators in terms of scaling agile in large-scale projects. The data were collected through surveys and

analytical hierarchy process (AHP) was employed analyze the responses. Finally, the 21 motivators of successful project management are grouped into four categories. Van Wessel et al. (2022) performed a case study to examine if enterprises can effectively manage agile and enterprise architecture in large-scale agile transformations. A conceptual model is developed with the purpose of effective application of enterprise architecture to agile-scaling frameworks.

Constructing multiple teams that work on the same product is also common in large-scale software development projects. Boutellier et al. (1998) explained the essential need of IT in large-scale international projects. Even though it has some drawbacks, international R&D teams provides global knowledge and perspective in order to serve international clients better. Therefore, the use of IT applications and services ease the management of dispersed teams at a company. Blau et al. (2011) employed agent-based simulation approach to search the information sharing and motivation mechanics in a large-scale software product development organization. The findings show that in complex environments, agent-based simulations are a promising technique to assess various incentive designs and derive professional suggestions. Also, rewarding procedure is suggested to be team-based value creation to prevent the selfish behavior of the members. J. M. Bass (2016) presented a novel classification model thereby gathering empirical data. The aim is to analyze large-scale agile method tailoring in two types of global software development program: offshore outsourced services and offshore captive development centers. Bjørnson et al. (2018) examined inter-team coordination in a large development program by employing g three mechanisms proposed by namely Shared Mental Models, Closed-loop Communication and Trust. The case study showed how relevant these three coordinating mechanisms and their combination improves the project's success. Kowalczyk et al. (2022) examined scaling agile development approach and presented organizational constraints, challenges, and corrective actions. Nordea Bank Abp was focused on during the study, thus, a customized SAFe framework was explained.

Many studies developed a framework, tool or methodology for process management. Anderson and Sheffler (1992) focused on project management methodology to support object-oriented Ada software development. Apart from the previously presented object-oriented methodologies, this concentrates on language-independent, mostly graphical, object-oriented solution that can answer the customer's requirements. The proposed methodology aims to control complexity and support management in various aspects. Feng et al. (1996) introduced a new perspective: the concept of concurrent engineering in manufacturing into software development. A tool named Concurrent Development Integrated Tool (CDIT) is presented which contains project management, system analysis, design, testing, generation, and maintenance. Komiya and Hazeyama (1998) developed a meta-model of work structure for software development projects management issue by using an object-oriented database and also a framework based on this meta-model. According to the experiments carried, both the meta-model and the framework is effective in software project management manner. Mead et al. (2001) put their attention to the notion of system survivability. It is suggested that survivability concerns should be treated as a requirement while developing a system, not as an add-on feature. The study proposed new methods to be applied in the development phase and a development life-cycle model containing survivability goals. Kouskouras and Georgiou (2007) studied a discrete event simulation model to monitor the software development process. By the help of this model, project managers were able to forecast delivery times and some quality metrics of their projects. Onions and Patel (2009) focused on Acceptance Test Driven Story Cards (SoBA) and its implementation to the different phases of development in order to enhance scalability, flexibility, management and control. Within the study, three improvement areas are pointed out with the integration of SoBA, which are architecture, project management and business analysis. Not any tests or cases are studied. Rao et al. (2008) presented a methodology based on Program Evaluation and Review Technique (PERT) and fuzzy logic to address the optimal PERT chart for project managers. The parameters considered are total cost, manpower and function points. The prototype serves as an object-oriented template for large scale and distributed projects. It also answers the questions related to vitality, quality, delivery date etc. that a project manager would care. Cottam et al. (2008) evaluated the growth of software projects towards their goal via routine testing. This research employed visualization techniques to understand the situation of software projects at different levels. These techniques are applied to the Open MPI project and MPI Testing Tool (MTT) as a toolkit was used. It was concluded that the visualization schema named as MTT Visualization Extension is an effective application for both Open MPI and other software projects to display the health of a development project. Sudaman and Mingins (2009) focused on managing outsourced software projects and proposed an infrastructure for routine reporting issue of these projects. This infrastructure Object-oriented Software Semantic Evolution Management (OSSEM) developed in the C# targeting the Microsoft .NET platform. It was prototyped and some limited tests are performed. It is aimed to be further developed and improve the performance. Wang et al. (2009) predicted software stage-effort by developing a grey models GM(1,1) and Verhulst, dynamically during the development process. The proposed model is compared with linear regression (LR) and the Kalman filter (KF) and the results showed that the proposed method is 28% and 50% more successful than the LR and KF. Vanhilst

et al. (2011) tackled the concern of measuring effort in a corporate organization. The goal is to generate a fundamental plan for an organization to monitor the progress. The data were gathered from the developers of Software Engineering Institute's CMMI level 3 or higher. They concluded that this empirical study could show the metrics available for effort and be repeated for any project within an organization. Besner and Hobbs (2012) performed research about project management toolsets. 2,339 experts are involved in this survey. While benefitting from component analysis, this study explains the pattern that what experts use as project management tools and techniques in groups or "toolsets." Comoretto et al. (2012) described The Information Management Tool (IMT) for The Gaia Data Processing and Analysis Consortium (DPAC). This consortium contains more than 400 professionals to develop large-scale software development, therefore, this work requires a process monitoring technique. For this purpose, DPAC presented IMT and used it in the management process. Kula et al. (2022) presented a conceptual framework that displays influential factors and their relationships to on-time delivery by examining mixed-methods case study at ING. Alam et al. (2022) statistically analyzed various software development process models using the six-pointed star framework. The data were collected through a survey which 26 companies. The analysis stated which software development process model should be used according to the scale of the project.

Some studies take a snapshot of the status of a project. Lee et al. (1994) presented PM-Net model to monitor the progress in software development processes. The Data Flow Diagram (DFD) and Work Breakdown Structure (WBS) techniques are employed in this model. By the help of this model, managers are going to observe the most recent project progress status at any time in the large-scale projects more effectively. Kettunen (2006) investigated problems occurring in large-scale new product development embedded software projects. Findings from the literature review and the author's professional expertise combined to generate an extensive matrix of probable project problems and to present a technique for evaluating projects' problem profile based on the matrix. The aim of this study is to guide project managers about the status of their projects and provide a holistic overview of it.

Apart from these studies, Eckstein (2014) explained the complexity issue for the architecture of large-scale developments and the impact of uncertainty and changes on it. Depending on the states of uncertainty and changes, three different models for architectural support are presented. Laanti and Kangas (2015) explained Portfolio Kanban board at Finnish Broadcasting Company Yle. The advantages listed by the users of this company is compared with the advantages in the literature. Heikkilä et al. (2015) presented how a release planning method was adopted in two case projects in a Finnish software company and listed the benefits and drawbacks that the projects gained from the method. Ten benefits and nine drawbacks are identified, in addition, the biggest improvements were said to be frequent status checks and a big visible planning status board. Scholtes et al. (2016) declared the negative correlation between the size of a project team and productivity by the analysis of 58 OSS projects.

3.2 Case Study Based Researches
Case study papers that they do not provide universal solutions but assess a specific case.

Phan et al. (1995) pointed out the key quality management and control problems in large-scale projects via a case study of IBM's development project. Several quality assurance strategies employed at IBM was explained. These strategies and the results obtained from the case study displayed the importance of high-quality commercial software in order to avoid defect removal costs and user dissatisfaction. The study of Aoyama (1998) suggested Agile Software Process (ASP) model based on ten-years of experience of development of a family of large-scale telecommunication software systems. During this experience, a shift from a sequential centralized process to a distributed concurrent process has happened. As a time-based process model, ASP has the goal to improve the delivery time by employing modular process structures, incremental and iterative processes. The application of APS in Japanese software industry, the development cycle-time was shortened by 75%, stability and utilization of workloads were increased, and flexibility and quality were improved.

Huen (2006) considered software offshoring topic with a case study. Offshoring is defined as relocating some of the company's operations to another country, mainly to an overseas country either by contracting with a different company in overseas or establishing a new office for the company in that overseas country. The case study revealed that offshoring is a need when considering market enhancement, lack of technical skills and schedule pressures. Leszak and Meier (2007) explained the partnership between a German and a Chinese work center for a large-scale global system and software development case. Organizational, sociological and technical key factors for successful try on this case are defined. Tiwana (2008) empirically studied the use of six key classes of development coordination tools on software development performance when the teams are multinational. According to the in-depth field study, there

is a relationship between the type of coordination tools and the type of novelty that the project is containing, namely, conceptual novelty, process novelty, both conceptual and process novelty, and neither of them. This paper is proposed as the first empirical study that mentions performance impacts of development coordination tools. Woodward et al. (2010) pointed out the enhancements which IBM Quality Software Engineering (QSE) gained by the help of scrum framework. Well-known organizational change management principles together with Scrum framework helped IBM to answer the customer need in the market quickly and improve the product value.

Schnitter and MacKert (2010) explained the transformation happened at SAP AG from waterfall approach to agile methodology. The experience itself was detailly describes in terms of lessons learned. Although it was still an ongoing change process, the transparency that Scrum brings found to be beneficial. Daneva et al. (2013) contributed to the literature by studying agile practices for requirements prioritization in distributed and outsourced projects. The findings show that dependencies are highly important for the success of project deployment. In addition, risk as a prioritization criterion is also crucial for outsourced large agile projects.

A case study in a Norwegian software development program was conducted to employ agile methods in a very large-scale development process. The results are interpreted as customer involvement, software architecture, and inter-team coordination are the key challenges for it (Dingsøyr et al., 2018). Moe et al. (2018) compared two large-scale software development programs to see the impact of having scheduled or unscheduled meetings. It showed that setting meetings is an important step in the beginning of a program and it provides a common understanding of domain knowledge. Stray et al. (2019) conducted a case study with five DevOps and 2 support teams to examine the dependency. At the end, 20 coordination mechanisms are defined, and it was stated that project management needs to integrate coordination mechanisms to handle dependency issue.

Bass (2019) explained the research obstacles in conducting large-scale software development programs using agile methods via workshop. Dingsøyr et al. (2019) listed suggestions from a large-scale development program with 12 scrum teams. These teams combined scrum with traditional project management perspective and all of them are concluded on budget and on time. Smolander et al. (2021) studied a 20-year-old enterprise systems development project to investigate the change in collaboration during a large-scale systems development project. Within this study, four collaboration modes are defined. Biesialska et al. (2021) extracted data from more than 70 teams running over a five-year period to explain the dependencies through user stories in large-scale distributed projects. According to the data set, 10% of the user stories have dependency among them but their effect is considerable.

3.3 Problem Solving Based Researches
Problem solving papers develop an algorithm to solve a problem during management processes. All these studies aim to optimize the total cost, makespan, process delay etc.

Ebert and Baisch (1998), Chang et al. (1998), Kinoshita et al. (2008) and Kroll et al. (2017) constructed a genetic algorithm for development processes. Liu et al. (2009) concentrated on two-stage probabilistic scheduling strategy to lessen the schedule overruns. Kolychev and Bezmenskii (2018) developed an algorithm for estimation of tasks' complexity to decrease the time spent for grooming and planning. Zalozhnev and Peremezhko (2022) constructed a mathematical model to optimize the supply chains for service operations at the implementation and maintenance stages of large IT projects.

3.4 Explanatory/Taxonomy Based Researches
Papers falling in this category explains the terms and conditions of project management concept. Among these six papers, half of them are based on agile/scrum framework.

Spencer et al. (2011) evaluated the role of project management and some forms of leadership in e-science. It was stated that the role of managers is crucial among the relationship of technology, people and environment. The clear outcome was that when the effectiveness of a manager decreases, the software quality decreases too. Nord et al. (2014) concentrated upon the architecture of a system development and defined what large scale means in terms of scope, team size, and project duration. Laanti (2014) focused on scaled agile term and explained its characteristics. In addition, the suggestions upon how to build scaled agility are listed. Dingsøyr et al. (2014) explained the scale of projects as a term and clarified what is a large projects and very large project based on requirements engineering literature. Alshammari (2022) compared scrum and Service-Oriented Architecture (SOA) frameworks in order to

assess if they are suitable together to improve the SOA-based projects. The study revealed as scrum to be chosen for a research and development project based on SOA. Faruk et al. (2022) focused on the effect of current software engineering processes and models including Agile, and DevOps in Blockchain Oriented Software Engineering (BOSE). The study acts as an overview of how to boost and succeed software processes for BOSE.

3.5 Literature Review Based Researches
There are five review papers within this field. All these review papers focus on agile framework. The literature lacks a comprehensive review study for project management concern.

Dingsøyr and Moe (2014) prepared a paper that acts as a kind of review paper from workshop at XP2014. Hoda et al. (2017) had the goal of reviewing agile software development topic. 28 papers published between late 1990s to December 2015 are investigated and they are categorized in ten research areas, namely, adoption, methods, practices, human and social aspects, CMMI, usability, global software engineering (GSE), organizational agility, embedded systems, and software product line engineering. Abrar et al. (2020) conducted a systematic literature review to identify de-motivators in the process of adopting agile for large-scale projects. 58 papers were reviewed, and 15 de-motivators were defined. Brasen and Tambo (2021) reviewed literature to explore the key theoretical fundamentals on agility related to management, leadership, and governance. The paper groups corresponding literature into 3 groups as they are the processes that relevant to organizational agile success, through management, leadership, and governance. The literature review study of Santos and de Carvalho (2022) identified key challenges and advantages of scaling agile methods to large projects. According to the 76 papers surveyed, 53 challenges and 32 advantages are defined.

4. Conclusion
WoS database is searched in detail to examine large-scale software development project management concept. 68 papers are reviewed within this study. These studies are clustered in 5 groups in terms of their research questions and topics. Nearly half of these papers are falling into the project management and monitoring category. These studies are mostly observing the agile transformation/adoption process or different aspects of agile project management phenomenon within firms and projects. In addition to this, studies are presenting new methods and tools to monitor the process of development. The second category is case study papers. These papers provide an understanding of a specific case and not suggests a universal application. The third is problem solving papers. They are generally proposing genetic algorithms to solve a problem during management processes. The fourth group is explanatory/taxonomy papers that explains any terms and conditions of project management concept. Finally, there are literature review papers which focuses on agile framework

To the best of authors' knowledge, the literature lacks a review study which provides an overview of project management of large-scale software product development concept that contains all project management frameworks in the literature. All the review studies found in literature (also summarized in Section 3.5) are focusing on agile development. There is not any comprehensive study within this field regardless of the management methodology.

There are 5 types of agile framework, namely, scrum, Kanban, extreme programming, crystal, and lean development. Among these 68 papers, mostly scrum framework is studied. It was observed that except one of these papers, Kanban teams have never been studied, yet. Examining Kanban methodology could be suggested as a future study. More statistics belonging the Kanban teams and related cases can be contributed to the literature. Moreover, extreme programming, crystal, and lean development cases are recommended to be examined as a future study. Furthermore, other scrum applications such as scrum of scrums and nexus scrums can be taken into account for further directions.

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