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Doctoral Thesis

Lean Project Management

An Application in Research and Technological Development (RTD) Projects

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Dedication and Acknowledgements

I want to dedicate and thank all the people involved directly or indirectly in this adventure and big challenge of doing a doctoral thesis.

Ibon, thank you for being part of my life, for always believing in me, for your continuous motivation, but above all for your unconditional love. Asko maite zaitut, amorcini! Ane, Jon, you are my engine every day, my inspiration to be a better person and to keep my enthusiasm. I love you with all my heart!

To my parents, thank you for your love and support throughout my life. Mom, you has been an inspiration to live my life bravely, with perseverance and honesty. Dad, thank you for teaching me to see life with humour and for giving me an example of hard work. To my siblings, my grandmother and every member of my family. Thank you for your love, your encouraging words and for accompanying me on this journey despite the distance.

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Abstract

In the current challenging business environment, competitive advantage is of vital importance to organisations. This leads to seek innovative approaches in order to optimise their processes. Moreover, there is a growing concern to improve the way projects are managed through the use of new tools and methodologies, which are different from the conventional ones.

Lean Thinking tools and principles have been proposed as one possible approach to this purpose. This approach can complement Project Management by focusing on creating value for the customer, continuous improvement and reducing non-value adding activities. The combined application of these two concepts together is known as Lean Project Management. Although Project Management methodology and the Lean approach have been extensively researched, little evidence has been found for their joint application.

The Lean Project Management approach is applied for project's performance improvement in a wide range of sectors such as construction, software development and even recently to research and development projects. For continuous improvement and management enhancement, it is crucial to define the organisation's Key Performance Indicators (KPI). Lean Project Management is of great support for this

purpose, as its principles and tools can be used to develop performance indicators and to identify improvement metrics.

The objective of this thesis is to investigate the integration of Lean Thinking with Project Management and its application in project-based organisations. The value of this thesis is threefold:

- It provides a comprehensive Systematic Literature Review of the published research to date concerning the application of Lean Thinking to the management of projects; the use of Lean Project Management approach; and the correlation with key performance indicators of the projects.
- A Lean Project Management model is presented framing Lean Thinking tools, techniques and principles blended with Project Management concepts and practices.
- A case study is conducted in a company based on Research and Technological Development (RTD) projects applying the proposed Lean Project Management model for the identification of KPIs.

This work also includes the findings and results of the author's own papers published at conferences and in scientific journals. These publications are cited throughout the thesis in the corresponding sections.

Chapter 1 Introduction

The present chapter provides an introductory overview of the thesis, by first discussing the background of the thesis topic as well as the justification for conducting the research. This section also introduces the problem statement; identifies the objectives and scope; sets out the research methodology; formulates three hypotheses to be answered through the research thesis; and outlines the structure of the thesis.

In today's competitive market, it is essential to have optimised management systems to be applied to projects (Ansah et al., 2016; Ballard et al., 2007). Researchers have argued that project managers must improve the way they manage projects, by adopting new tools and methodologies beyond the traditional ones (Ansah et al., 2016; Cruz-Villazón, 2018). Project Management concepts, methods and instruments are being reinforced through the integration of quality disciplines such as the Lean approach (Reusch & Dechange, 2013).

Selecting the appropriate resources, techniques and methods is essential for meeting customers' needs (Rebaiaia and Vieira, 2014 as cited in Cruz-

Villazón, 2018). According to (Ansah et al., 2016) it is clear that solid and practical approaches to Project Management are needed for addressing these challenges.

Tackling economic and technological challenges is a daily struggle for organisations to be competitive in complex environments. To face these issues, an effective strategy to identify, measure, understand and control their business performance is required (Cruz-Villazón et al., 2020). Lean is seen as a complementary approach for managing projects by focusing on value creation from the customer's perspective and the elimination of waste (Cruz-Villazón, 2018).

1.1 Context and Motivation

Project management performance improves by strengthening its capability of meeting the needs of the customers (Horman & Kenley, 1996). The application of Lean has been studied as a suitable methodology to complement Project Management practices (Howell and Koskela, 2000 as cited in Cruz-Villazón, 2018) by focusing on continuous improvement, creation of value for the costumer and waste eliminations such as project's timeline and costs (Moujib 2007; Nieto-Morote and Ruz-Villa, 2015 as cited in Cruz-Villazón, 2018). Lean tools can bring a significant improvement to the management of projects (Cruz-Villazón, 2018).

The joint application of the Lean approach and Project Management has been referred to as Lean Project Management and has been the subject of research in recent years (Ansah et al., 2016; Ballard et al., 2007). The principles and tools of Lean Project Management have been spread widely in manufacturing, moving far beyond the automobile sector and the shop floor into white collar functions (Ballard et al., 2007). Its application to improve project performance can be detected in sectors, such as construction, software development and even, recently, in research, technological and development (RTD) projects. However, while Lean Project Management in the above-mentioned sectors is well established, limited research has been found for RTD projects.

For continuous improvement and management enhancement, it is crucial to define the organisation's Key Performance Indicators (KPI). Lean Project Management is of great support for this purpose, as its principles and tools can be used to develop performance indicators and to identify improvement metrics.

Even though Lean Thinking is a recognized approach for creating value and reducing process waste, limited research has been conducted on the link with Project Management. Comprehensive guidelines for project managers on the day-to-day use of Lean tools and principles are lacking. Due to its origin in production, most of the available literature concerns to the application of Lean Thinking in that field. However, in the last twenty years, research has been conducted on its use in other sectors (Cruz-Villazón, 2018).

Furthermore, combining Lean and Project Management is a practice introduced quite recently. This study aims to investigate the authors, concepts and practices that have been explored within this field particularly in RTD projects.

Adopting KPIs to meet targets in production environments is widespread (Dombrowski et al., 2013a). However, there is scarce published research on the development of a model to identify KPIs in project-based companies. There was also found an inconsistency in the process of identifying and measuring KPIs (Cruz-Villazón et al., 2020).

In this thesis it is analysed and proposed that the principles and methods of Lean Thinking can be used for identifying KPIs within organisations that are based on projects in accordance with their organisational and operational requirements. It makes use of two methods. The first is a conduction of a Systematic Literature Review (SLR) for gathering information on topics such as: Project Management practices, Lean Thinking principles and tools, and Lean Project Management, project success and KPIs. And second, an analysis of a case study applying Lean Project Management in RTD project-based company.

1.2 Objectives and Hypothesis Formulation

Lean principles, tools and techniques, as well as Project Management concepts will be the main focus of this thesis. The scope is to investigate how the application of Lean to the management of projects can lead to the improvement of their performance. Considering this the following hypotheses are proposed

Hypothesis 1: The combination of Lean Thinking principles and tools and Project Management practices can be applied in conjunction.

Hypothesis 2: Lean Project Management has a positive impact for project performance.

Hypothesis 3: In project-based companies, Lean Thinking covers the required aspects in order to manage their key performance indicators.

The scope of this study is the application of Lean Thinking in Project Management, especially in RTD projects. Concerning Project Management, even though there are several guides for these practices, the PMI's sixth edition Project Management Body of Knowledge (PMBOK) Guide will be used as reference. These guidelines compile all the principles of good practice for the management of projects and, according to (Anholon & Sano, 2016), its choice is justified since its standards are currently considered the leading ones in the field.

There are basic books explaining the origins and background of the Lean approach. Furthermore, there are manuals with more practical information regarding the application of this methodology in organisations. It is outside the scope of this research to analyse in depth a Lean implementation program.

Lean Thinking is a way of thinking, a value-based mind-set. Throughout this thesis the term "Lean" is used to refer to the complete concept of Lean as this definition, including its principles and its related tools. The scope of this thesis is to cover the Lean Thinking aspects.

Gaps in the literature were identified and were used to formulate the research questions and the thesis methodology.

1.3 Thesis Structure

This study is divided into two parts. The first part describes in depth the concepts of Lean Thinking and Project Management individually followed by an analysis of the contribution of these two methodologies, when integrated, to the performance of project-based organisations. For this first part, a Systematic Literature Review is carried out. In the second part of the thesis, a Lean Project Management model is developed for the identification of performance indicators of project-based organizations. This is applied to a case study of an RTD project-

based company to be analysed through the proposed mode in order to identified performance indicators. And finally, results and findings are presented and discussed, along with conclusions and some suggestions for future research.

Figure 1 illustrates the structure of this thesis and outlines the nine chapters comprising its contents. Chapter 1 Introduction contextualizes the research in the corresponding literature and presents the topics to be covered throughout the study. Chapter 2 Followed Methodology: outlines the research design, the deductive and inductive approaches and explains the selected qualitative method.

The theoretical part of the thesis is presented in Chapter 3 Project Management offers a review of the evolution of the scientific research on Project Management. In Chapter 4 Lean Thinking a SLR was carried out to analyse the published material on Lean. This section explores the origins and evolution of the Lean approach. It also explains the concepts behind this philosophy such as its principles, the focus on value, and the different types of waste from a Lean perspective. In addition, it describes the tools and techniques used in Lean.

Chapter 5 Lean Project Management contains a comprehensive analysis of the information compiled on Lean Project Management as an embedded concept. In this section the SLR is developed. It discusses the use of Lean in project-based organizations by analysing its application in different sectors. Apart from this applicability, it is investigated the way it can aid in identifying performance

indicators. Concepts related to KPIs, indicators, metrics to measure performance and success factors related to projects are also explored.

A Lean Project Management model is developed based on Lean principles and tools for the identification of KPI's in Chapter 6. The theoretical concepts reviewed in the previous chapters provide the basis for designing this model. In addition, throughout the development of this model, It is embedded elements related to projects success factors and Lean methods linked to performance measurement.

The empirical part of this study was conducted in Chapter 7 Case Study. The proposed model is also validated in this chapter. The outcomes from the Systematic Literature Review regarding to the application of Lean Project Management are applied to a RTD company presented as a case study.

Chapter 7 Results and discussions: shows the findings on the use of Lean Project Management in project-based organizations for performance improvement. In the last section, Chapter 8 Conclusions: significant deductions, limitations and directions for further research are provided.

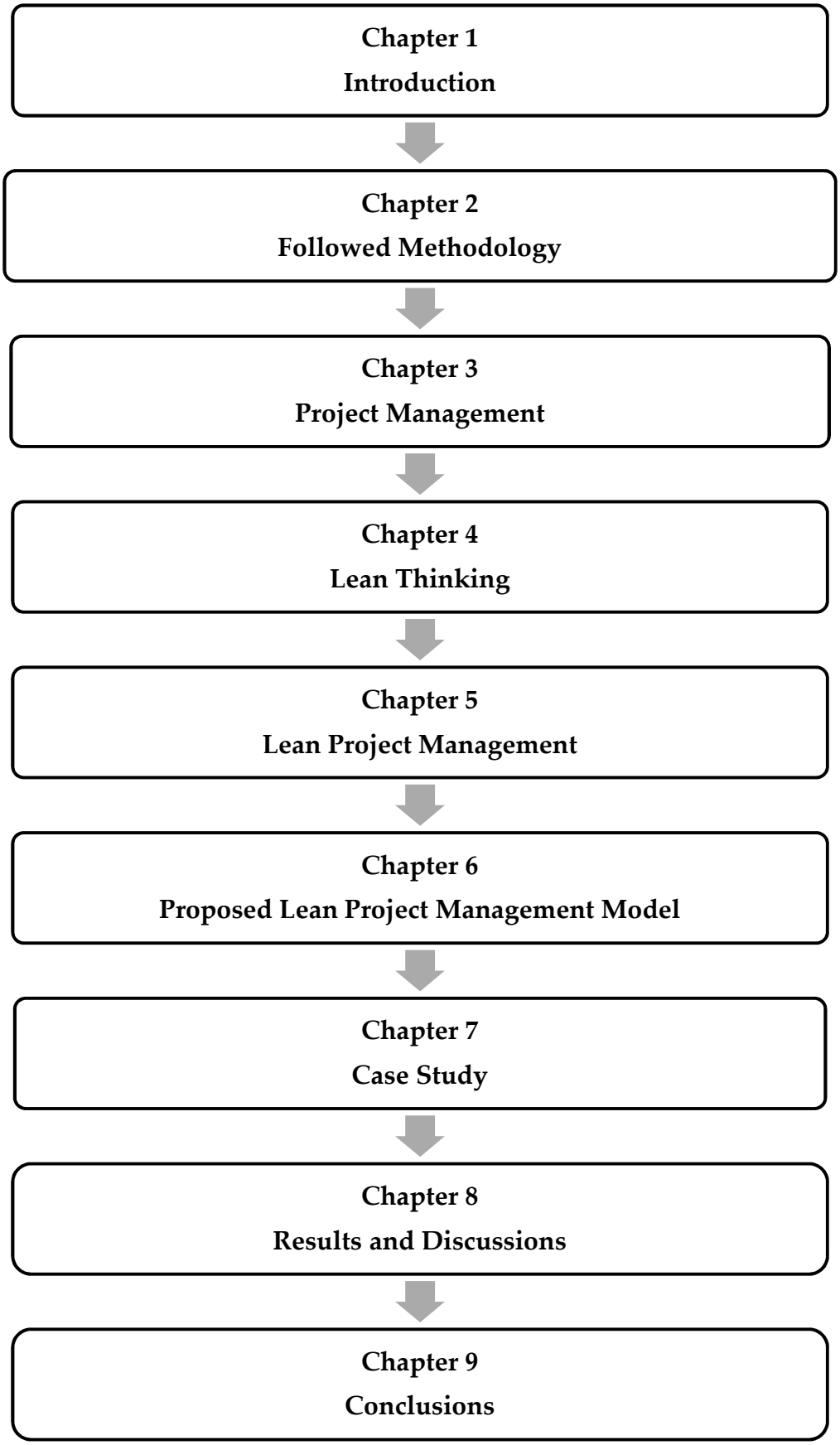

Figure 1: Structure of the thesis (Source: Author)

Chapter 2 Followed Methodology

The methodologies used for the elaboration of this thesis are divided in two parts. First, a rigorous and exhaustive SLR was conducted to examine the existing information on the subjects. The main findings and outcomes of the SLR of this study are presented in this chapter. The SLR provides a theoretical background covering the main topics individually and a critical analysis linking the main points. The second part comprises of the application of a Lean PM model, developed with the information obtained from the literature to a case study of an RTD company.

A methodology is an overall research strategy outlining the research approach while ensuring coherence between the tools and techniques chosen (Melnikovas, 2018). It encompasses theoretical and philosophical premises used to frame the research questions and justify decisions concerning the methods to be used in the research (Melnikovas, 2018).

The research design is about which approach will be followed in order to gather and analyse the data on the research topic. This section explores the development of the selected research design for methodological coherence.

2.1 Research design

Based on Saunders' "Onion Research", the design of the methodology for this thesis can be defined as follows. The theoretical concept of the "Research Onion" developed by Saunders et al. (2016) was taken as reference for the development of the research methodology of this thesis (Figure 2). It was considered as a source for the methodology of this approach to develop a richer theoretical perspective from what currently appears in the literature (Saunders et al., 2016).

The "Onion Research" comprehensively describes the main steps that need to be fulfilled for an accurate methodology to be designed (Saunders et al., 2016). This research methodology initiates by outlining the principal philosophy, followed by the choice of approaches, as well as methods and strategies. Time horizons are also defined, bringing logic to the research design along with data collection and analysis techniques and procedures. (Melnikovas, 2018).

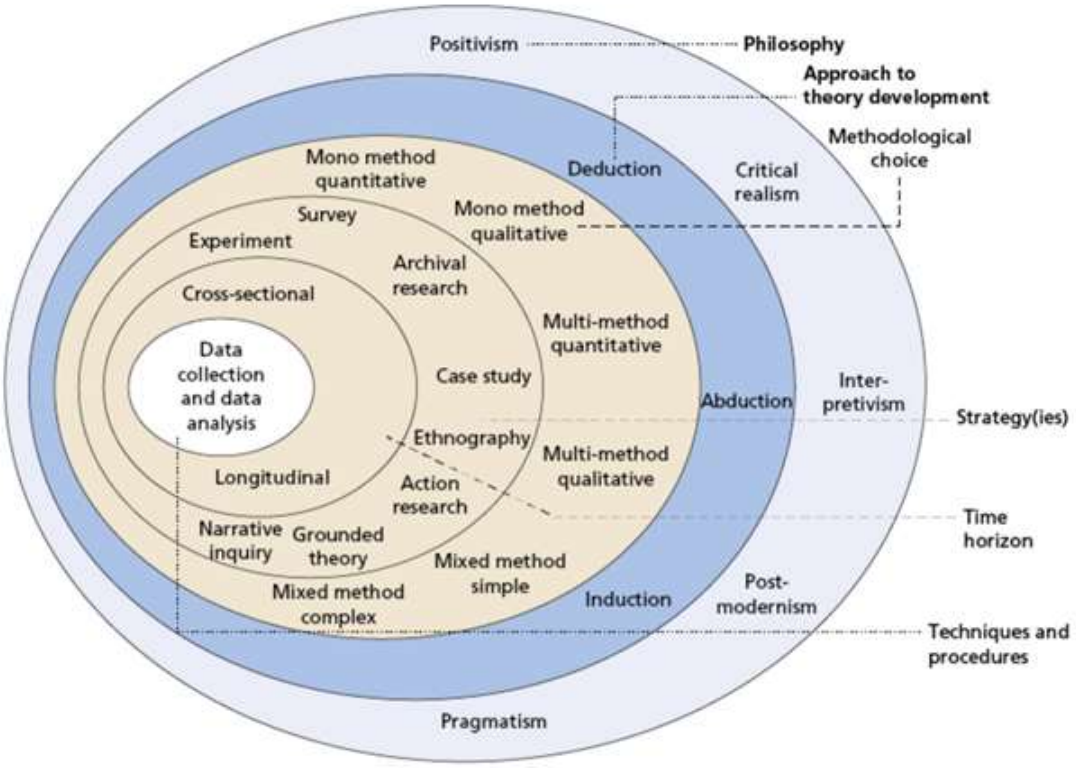

Figure 2: "Onion Research" design (Source: Saunders et al., 2016)

An SLR and a case study were the research strategies selected for developing this thesis. This choice was based on the research questions, objectives and scope provided by the study. The methodological choice employed was the simple mixed method, since each section of the thesis was carried out using a different method.

The time horizon for the SLR section applied was longitudinal, given that the published data was collected over a given period of time. However, for the case study, the time horizon applied was cross-sectional, since it involved the study of a single event at a specific point in time.

The technique and procedure used in this work for data collection was a Systematic Literature Review (SLR). The SLR was used to establish the scope and terms of the research topic; to give a rationale for the selection of the reviewed literature; then to connect the research with the literature; and finally, to analyse the findings and to identify possible gaps (Cruz-Villazón, 2018). SLR is recognised as a valid approach to ensure transparency and replicability of the research (Garza-Reyes, 2015).

2.2 Systematic Literature Review (SLR)

The research methodology selected was a SLR. It was decided to use the SLR mainly for the fact that it is "a systematic, explicit, comprehensive and reproducible method for identifying, evaluating and synthesising the existing body of completed and recorded work produced by researchers" (Okoli & Schabram, 2010 as cited in Panayiotou & Stergiou, 2021).

It was followed the five steps SLR process (Figure 3) consisting in the following five consecutive phases (Garza-Reyes, 2015; Saunders et al., 2016)

1) ***Question formulation:*** formulation of the review questions.
2) ***Locating publications:*** identification and creation of a compiled list of relevant existing research studies.

3) ***Selection and evaluation of publications****:* relevant research studies are selected and evaluated according to explicit predefined inclusion and exclusion criteria.
4) ***Analysis and synthesis:*** break down the studies into component parts to explore and summarize the studies for answering the review questions.
5) ***Report and use findings:*** findings and discussions are presented.

In each of the SLR phases, the objective, method and tool are outlined and it is mentioned in which chapter the information can be found. With the collected information, a bibliometric analysis was made to organize the outcomes of the research done. Then the concepts were analysed and classified with a thematic analysis.

Figure 3: SLR phases, methods, tools and location (Source: adapted from Cruz-Villazón, 2018)

Following the SLR phases described in Figure 3, the process begins with the formulation of the research questions. To conduct this SLR, key goals need to be achieved. Depending on the research topic questions should be selected according to inclusion and exclusion criteria.

2.2.1 Research questions formulation

In order to have a setting for the development of the SLR, the following research questions were formulated. These questions were defined according to the context and the topics under investigation for this work. The first two research questions (RQ1 and RQ2) concern a general focus of the concepts of Lean, its principles and tools; the practices of Project Management; and the possible link between both approaches. RQ3 and RQ4 were proposed for a more specific focus on the application of Lean in RTD project-based organisations and the process of identifying KPIs. The questions that the SLR aims to answer are the following:

RQ1: What can Lean contribute to Project Management?

RQ2: How can Lean be applied in project-based organisations?

RQ3: Which are the benefits of using the Lean approach for the identification of KPI measurement process?

RQ4: In which way a model for the identification of KPIs developed with Lean will benefit RTD project-based organisations?

2.2.2 Location and Selection of Publications

The choice of the databases used in the compilation of the publications was based on recognition by other researchers for the quality and variety of their content. The Scopus engine, the Web of Knowledge (WoK) database, SinceDirect and Google Scholar were selected to obtain the relevant publications (Table 1).

To enter the keywords in the databases it was chosen the "Title, abstract or author-specified keywords" option. The Boolean operator "AND" has been applied for combining the keywords together in order to narrow down the results of the search (Table 1). The range of years was not specified in order not to limit the number of publications. For the "Location of Publication" and "Publication's selection and Evaluation" steps of the Systematic Literature Review, the identified papers were examined based on the inclusion and exclusion criterion outlined in Table 1. The main research focus concerned the link of Lean and Project Management, Lean in project-based organizations, and Lean with the performance indicators in project-based context.

After an accurate screening process of the literature available, the publications were identified as relevant and were selected to be analysed. It was the result of applying the defined exclusion criteria. The abstracts were reviewed to verify that those papers either answered any of the defined research questions or at least contributed with some input to this study. After these steps a number of 103 documents was obtained (Appendix A).

Table 1: *Research methodology (Source: Author)*

Unit of analysis	The sources include peer-reviewed journal papers, conference articles, proceedings, and book chapters.
Type of analysis	Qualitative and quantitative
Search databases	Science Direct, Web of Science (WoS), Scopus, Google Scholar
Keywords for the search	The following combination of terms was used for the search criteria for each section of the thesis. **Methodology** lean AND "Systematic Literature Review" project management AND "Systematic Literature Review" lean AND "case study" project management AND "case study" **SLR for Lean** lean AND thinking lean AND evolution lean AND tools lean AND six sigma

lean AND value

SLR for Project Management

project management AND methodology

project AND PMBOK

project AND success

SLR for Lean Project Management

lean AND project

lean AND "project management"

lean AND construction

lean AND software OR "information technology"

lean AND R&D

lean AND project-based

SLR for Lean Project Management and KPI

lean AND KPI

lean AND KPI AND project

lean AND performance AND indicator

lean AND performance AND project

lean AND performance AND R&D

lean AND project AND R&D

lean AND research AND development

DMAIC AND KPI

"Project management" AND KPI

project AND performance

project AND success

Inclusion criteria	• Papers, articles, lecture notes, conference proceedings. • Only documents in English and Spanish were considered.
Exclusion criteria	• Papers in which the term "lean" was used in a different context from the focus of this paper. • Duplicated papers among the databases. • Patents and citations were not considered. • There is no relation between paper and research topic.
Total number of articles analysed	Considering the parameters of this table, the following number of papers were selected for this study for Lean Project Management a total of 103.

After searching for the terms in the databases, a first screening was carried out by applying the exclusion criteria previously defined. Duplicated documents were eliminated, as well as those considered to be outside the scope of the topics. The next step was to read the abstracts to ensure that the papers were useful for answering the research questions. Afterwards the selected publications were fully reviewed. As a result, a total of 103 papers about Lean Project Management were selected to be included and analysed.

For the management of publications and references, it was used the reference management and knowledge organization program called Citavi (from Microsoft

Windows). The selected publications were managed with Citavi. The analysis and display of the data were performed with Excel.

This process of SLR then proceeded to the fourth step in which publications were analysed. This step was carried out by means of a descriptive analysis followed by a synthesis of the information collected. Finally, the last step was to report and use these results. In the Thematic Analysis section, the report is presented in Chapter 5 Lean Project Management and applied in Chapter 5 Lean Project Management Model for the development of the model. The insights for conducting the case study were used in Chapter 7 Case Study - CFAA and the findings discussed in Chapter 8 Results and Discussion.

2.3 Case Study Research Strategy

The case study research strategy helps to gain a deeper understanding of a topic and it is useful to bring it within a realistic context. It is an empirical investigation of a concrete event in its real environment using a range of existing evidence sources (Saunders et al., 2016). In particular, a qualitative approach was applied for the analysis of the case study in this thesis. This approach allows researchers to conduct a detailed investigation of complex issues embedded in a specific situation. (Rashid et al., 2019).

This approach can be tackled according to the epistemological perspective of the researcher (Saunders et al., 2016). It consists in following a comprehensive and detailed research, generally based on empirical evidence collected during a specific period of time. To conduct a case study aims to carry out an investigation focusing on a specific case, such as an individual, group, institute or community, allowing for the identification of key factors, processes and relationships (Rashid et al., 2019).

The case study conducted in this thesis followed as a basis the work of (Rashid et al., 2019) which provides a proposed systematic guide for conducting case studies in the framework of a supportive literature review. The case study was carried out within a project-based company that mainly works with RTD projects. It consisted in the application of the Lean-based KPI model developed during the thesis for the identification of KPIs.

Chapter 3 Project Management

This chapter begins with a literature review of the encompassing conceptual and theoretical background of Project Management. It is intended to provide an in-depth survey of what has been published so far in this field. The main frameworks of managing projects, project processes and knowledge areas are also presented, as well as exploring the key issues of project performance and project success.

3.1 Theoretical background of Project Management

Organizations, regardless of the sector, are increasingly using projects to meet their strategic objectives. Projects can be diverse in nature, such as innovation projects, improvement projects, new product development projects, expansion projects, among others (Sousa et al., 2018). One of the advantages of project management is the alignment of project objectives with strategic objectives, increased communication

throughout the organization, the use of common assets for standardization (Sousa et al., 2018). Therefore, in recent years, there has been a growing interest in the notion of Project Management as a means to implement the organisation's strategy.

A project is defined as *"a temporary endeavour undertaken to create a unique product, service or result"* (PMI, 2021). "Temporary" means that it has a specific starting and ending time point also with a defined scope as well as assigned resources. It is essentially unique due to the fact that it is not a routinized activity. In a project, this is a set of actions designed to accomplish a specific goal (PMI, 2021).

Project Management is described in the PMBOK (2017) as *"is the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements. Project management is accomplished through the appropriate application and integration of the project management processes identified for the project. Project management enables organizations to execute projects effectively and efficiently."*

Project Management processes and methods may be considered as directives designed to support and guide project managers (Sousa et al., 2018). Project Management is considered as a universal methodological framework (Anholon & Sano, 2016) that defines the *"of knowledge, skills, tools, and techniques to project activities to meet the project requirements"* (PMI, 2021). The traditional Project Management is also referred as "waterfall approach" and it is built upon the premise that a single set of

guidelines can be used for all kinds of projects, independently from their level of complexity or sector of implementation (Tödtling et al., 2017).

Despite the attempts to identify the causes of an under-performing Project Management, researchers have drawn the inference that the reason is "the way in which projects are managed" (Sohi et al., 2016). Besides the relevance of the general Project Management practices, the size differences, the singularity, and the complexity of the projects highlight the need for customized Project Management methods (Sohi et al., 2016). Project Management need to be tailored to the current dynamic business environment (Sousa et al., 2018). Nowadays, a "traditional" Project Management approach has become ineffective (Sohi et al., 2016).

A number of published frameworks for Project Management are available. These guidelines were developed, implemented, and promoted within recognized and widely acknowledged organizations (Rania, 2010). These guidelines were developed, implemented, and promoted within recognized and widely acknowledged organizations (Rania, 2010). They all have their own strengths and benefits in various fields of application (Rania, 2010).

The most relevant Project Management standards include the following (Rania, 2010; Sanjuan & Froese, 2013):

- ***ICB*** - Individual Competence Baseline launched by the International Project Management Association (IPMA).

- ***ISO 10006*** - Guidelines for quality management in projects published by the International Organization for Standardization (ISO).
- ***P2M*** - Project and Program Management by the Engineering Advancement Association of Japan
- ***PMBOK*** - Project Management Body of Knowledge Guide released by the Project Management Institute (PMI).
- ***PRINCE2*** – Projects in Controlled Environments issued by the Office of Government Commerce (OGC) of the United Kingdom.

These frameworks are comprehensive and are intended to embrace every aspect within Project Management. However, the PMBOK has been regarded as one of the leading and widely recognised guidelines and as the most generic and traditional framework for project management (Rania, 2010). Therefore, throughout this thesis the PMBOK 6th edition will be used as a frame of reference regarding the management of projects.

3.2 PMBOK 6th Guide

The Project Management Body of Knowledge (PMBOK) Guide is the main reference book on the fundamentals of Project Management published by the PMI.

This is a cornerstone resource for any industry and for all projects and it recognises a particular subset of the body of project management knowledge commonly considered as good practices (PMBOK, 2017).

The PMBOK Guide provides the Standard for Project Management which is the framework on which the vast body of knowledge is built, serving as a roadmap for capturing and synthesising knowledge (PMI, 2022). To manage a project, the processes, inputs, tools, techniques, outputs and life cycle phases must be tailored accordingly (PMBOK, 2017). Customization is needed since every project is unique and not all processes and tools are suited to all projects (PMBOK, 2017).

> ***"To manage a project, the processes, inputs, tools, techniques, outputs and life cycle phases must be tailored accordingly. Customization is needed since every project is unique and not all processes and tools are suited to all projects."***
>
> *PMBOK (2017)*

According to the PMBOK, any project can be represented by a generic life cycle (Figure 4). It comprises a set of phases (sequential, iterative, or overlapping) which a project follows from its initiation to its closure. It gives a fundamental guideline to manage projects and is applicable independently from the specific work involved in the project (PMBOK, 2017).

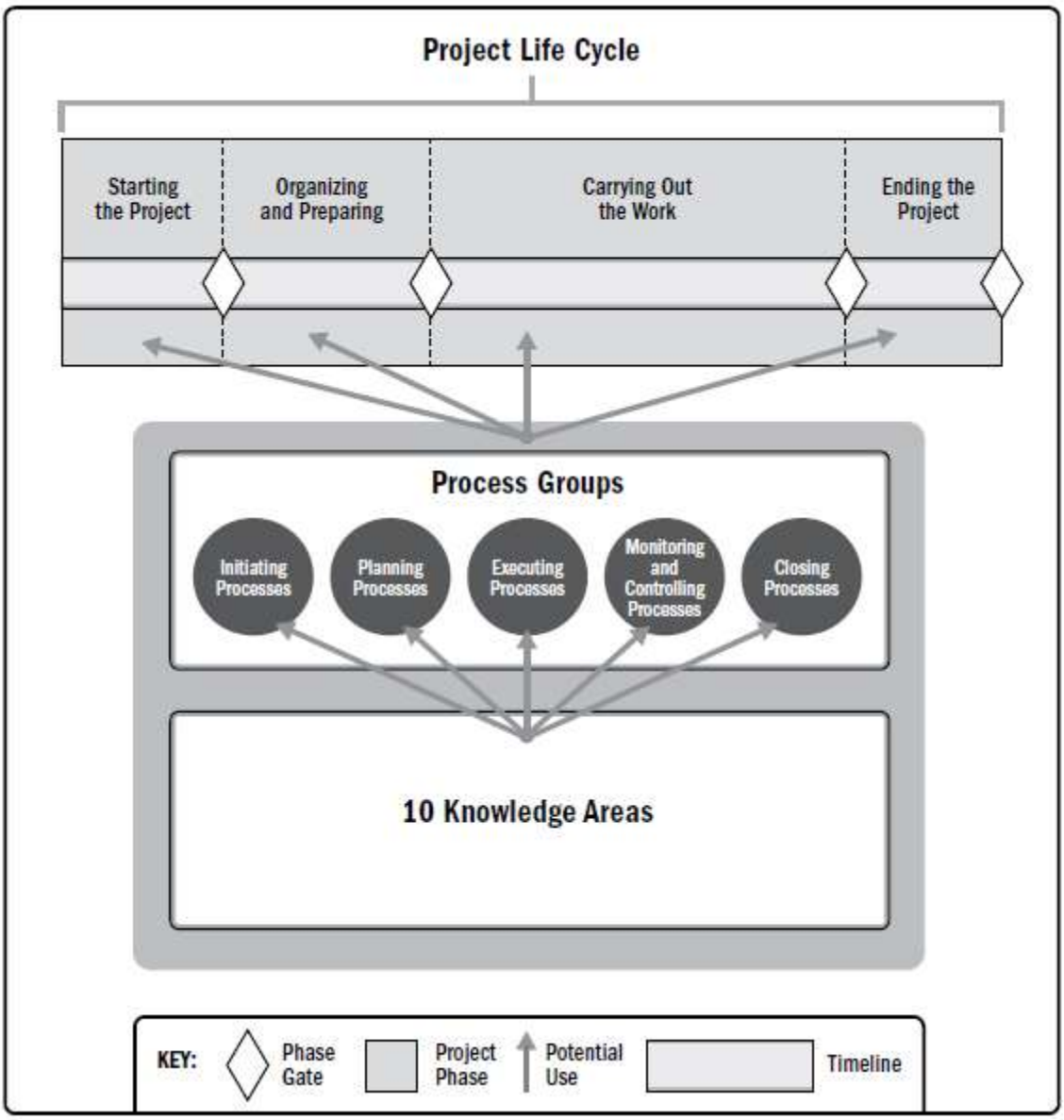

Figure 4: Generic project life cycle (Source: PMBOK, 2017)

There are usually one or more phases within the life cycle of a project that are related to product, service or result development (PMBOK, 2017). Each defined PM process inside the knowledge areas and process groups are outlined by inputs, inputs, tools and techniques (Sanjuan & Froese, 2013).

The project management team is in charge of determining which type of life cycle is most suitable for each project. Therefore, ensuring that the life cycle of each project is flexible enough to adequately address the variety of factors involved in the project is crucial (PMBOK, 2017).

The PMBOK 6th edition consists of 47 processes and ten main knowledge areas, which are divided in these five phases: (1) Introduction, (2) Planning, (3) Execution, (4) Monitoring and Control, and (5) Closure. Those phases constitute the project lifecycle as shown in Table 2.

Table 2: *Project Management Process Group and Knowledge Area Mapping (Source: PMBOK, 2017)*

Knowledge Areas	**Project Management Process Groups**				
	Initiating	**Planning**	**Executing**	**Monitoring and Controlling**	**Closing**
4. Project Integration Management	4.1 Develop Project Charter	4.2 Develop Project Management Plan	4.3 Direct and Manage Project Work 4.4 Manage Project Knowledge	4.5 Monitor and Control Project Work 4.6 Perform Integrated Change Control	4.7Close Project or Phase
5. Project Scope Management		5.1 Plan Scope Management 5.2 Collect Requirements 5.3 Define Scope 5.4 Create WBS		5.5 Validate Scope 5.6 Control Scope	
6. Project Schedule Management		6.1 Plan Schedule Management 6.2 Define Activities		6.6 Control Schedule	

	6.3 Sequence Activities 6.4 Estimate Activity Durations 6.5 Develop Schedule		
7.Project Cost Management	7.1 Plan Cost Management 7.2 Estimate Costs 7.3 Determine Budget		7.4 Control Costs
8. Project Quality Management	8.1 Plan Quality Management	8.2 Manage Quality	8.3 Control Quality
9. Project Resource Management	9.1 Plan Resource Management 9.2 Estimate Activity Resources	9.3 Acquired Resources 9.4 Develop Team 9.5 Manage Team	9.6 Control Resources
10. Project Communicat	10.1 Plan Communications Management	10.2 Manage Communications	10.3 Monitor Communicat ions

ions				
Management				
11. Project Risk Management		11.1 Plan Risk Management 11.2 Identify Risks 11.3 Perform Qualitative Risk Analysis 11.4 Perform Quantitative Risk Analysis 11.5 Plan Risk Responses	11.6 Implement Risk Responses	11.7 Monitor Risks
12. Project Procurement Management		12.1 Plan Procurement Management	12.2 Conduct Procurements	12.3 Control Procurements
13. Project Stakeholder Management	13.1 Identify Stakeholders	13.2 Plan Stakeholder Engagement	13.3 Manage Stakeholder Engagement	13.4 Monitor Stakeholder Engagement

Tailoring becomes essential since every project is unique. Project Management processes, tools, techniques, techniques, inputs, deliverables and outputs need to be thoroughly chosen to deal with the various constraints in terms of scope, timing,

budget, resources, quality and risks (PMBOK, 2017). Moreover, the use of particular methodologies for the management of projects is required in certain organizations (PMBOK, 2017).

To manage complex projects properly, the project management methodology and the tools involved need flexibility or adaptability (Kerzner, 2017). A new project management approach should be deployed for each stakeholder interaction, considering the different requirements and expectations they can have, coupled also with the long-term nature associated to complex projects (Kerzner, 2017).

3.3 Project Management Processes Groups

Project life cycle is handled through the execution of a set of project management actions commonly called project management processes. Each of these processes generates outputs from the inputs by using suitable tools and techniques. The output is either a result or a deliverable, being the end result of the process. These processes are widely applied in all sectors (PMBOK, 2017).

The PMBOK groups the Project Management processes in a logical way to meet the specified project goals. They are independent of the project phases (PMBOK, 2017). These fall into the following five groups of Project Management processes (PMBOK, 2017):

Initiating Process Group. Those processes performed to define a new project or a new phase of an existing project by obtaining authorization to start the project or phase.

Planning Process Group. Those processes required to establish the scope of the project, refine the objectives, and define the course of action required to attain the objectives that the project was undertaken to achieve.

Executing Process Group. Those processes performed to complete the work defined in the project management plan to satisfy the project requirements.

Monitoring and Controlling Process Group. Those processes required to track, review, and regulate the progress and performance of the project; identify any areas in which changes to the plan are required; and initiate the corresponding changes.

Closing Process Group. Those processes performed to formally complete or close the project, phase, or contract.

3.4 Project Management Knowledge Areas

Process groups within the PMBOK are also classified by Knowledge Areas which are areas related to their knowledge requirements and outlined by their

component processes, practices, inputs, outputs, tools and techniques (PMBOK, 2017). The Knowledge Areas are linked to each other and are utilized throughout the majority of the projects. This PMBOK describes ten Knowledge Areas as follow:

Project Integration Management. Includes the processes and activities to identify, define, combine, unify, and coordinate the various processes and project management activities within the Project Management Process Groups.

Project Scope Management. Includes the processes required to ensure the project includes all the work required, and only the work required, to complete the project successfully.

Project Schedule Management. Includes the processes required to manage the timely completion of the project.

Project Cost Management. Includes the processes involved in planning, estimating, budgeting, financing, funding, managing, and controlling costs so the project can be completed within the approved budget.

Project Quality Management. Includes the processes for incorporating the organization's quality policy regarding planning, managing, and controlling project and product quality requirements, in order to meet stakeholders' expectations.

Project Resource Management. Includes the processes to identify, acquire, and manage the resources needed for the successful completion of the project.

Project Communications Management. Includes the processes required to ensure timely and appropriate planning, collection, creation, distribution, storage, retrieval, management, control, monitoring, and ultimate disposition of project information.

Project Risk Management. Includes the processes of conducting risk management planning, identification, analysis, response planning, response implementation, and monitoring risk on a project.

Project Procurement Management. Includes the processes necessary to purchase or acquire products, services, or results needed from outside the project team.

Project Stakeholder Management. Includes the processes required to identify the people, groups, or organizations that could impact or be impacted by the project, to analyse stakeholder expectations and their impact on the project, and to develop appropriate management strategies for effectively engaging stakeholders in project decisions and execution.

Over the past few years, the PMI has been issuing extensions relating to selected areas of application of the PMBOK Guide. Such supplementary annexes are published as "PMBOK Extensions", "Practice Standards" and “Practice Guides”. “PMBOK Extensions” offer a general guidance on Project Management applicable to

a specific industry (PMI, 2021). These sectors currently included are Construction, Software and Government. There are six "Practice Standards" covering in depth important aspects of the management of projects such as Risk Management, Earned Value Management, Work Breakdown Structures, Scheduling and Project Estimating. Finally, to date there are seven "Practice Guides".

The latest incorporation was the "Agile Practice Guide" in 2016 as part of the sixth edition of the PMBOK Guide. The other "Practice Guides" contain in-depth topics such as Requirements Management; Governance of Portfolios, Programs, and Projects; Business Analysis; Implementing Organizational Project Management; Navigating Complexity; Managing Change in Organizations (PMI, 2021).

3.5 Project Success and Project KPIs

Nowadays, organizations are recognizing the importance of improving the performance of their business. To achieve this goal, it is essential to identify, measure, understand and control the performance progress (España et al 2012; Iuga et al. 2015). The measurement systems for setting organisational objectives and for monitoring improvements by tracking effectiveness and efficiency are required (Zakaria et al., 2011).

The success of projects, together with the factors impacting it, is a topic that has been extensively discussed in Project Management research (Cruz-Villazón et al., 2020). Nevertheless, deciding whether or not a project will succeed or fail is regarded as one of the main challenges (PMBOK, 2017). It is generally defined as a successful project if it fulfils the needs and expectations of the stakeholders (Sanjuan & Froese, 2013).

This concept has been investigated by practitioners and academics based on the definition of success in terms of the iron triangle of time, cost and quality (Cruz-Villazón et al., 2020; PMBOK, 2017). Sanjuan & Froese (2013) stated that frequently the stakeholders' interests are met once the project is delivered on time, within budget, inside the scope and with the expected quality. The authors also note that the criteria for project success are subjective and are set by the stakeholders.

This leads to recent assertions such as the statement that project success has to be measured in terms of the degree to which the project objectives are achieved (PMBOK, 2017). For a project to be truly successful, it is necessary to deliver value at project completion (Kerzner, 2017). Fulfilment in time and cost constraints do not ensure that business value is achieved (Kerzner, 2017).

Two different components can be distinguished regarding project success: project success factors and project success criteria (Cruz-Villazón et al., 2020). The former refers to the elements of a project whose influence increases the probability of

success such as stakeholder, risk and quality management, etc. (Lim & Mohamed, 1999 as cited in Cruz-Villazón et al., 2020). The second ones are the measures for judging project success or failure, such as stakeholder satisfaction, cost, scope, time, among others (Lim & Mohamed, 1999 as cited in Cruz-Villazón et al., 2020). Project success also encompasses further criteria associated with business strategy and the achievement of results in terms of business performance (PMBOK, 2017).

Kerzner, (2017) suggests meeting with the customer and stakeholders at the beginning of the project in order to establish agreements regarding success criteria for the project. Commonly, at an early stage of the project, the stakeholders can have their own interpretation of success, but agreement is necessary to reach a common understanding (Kerzner, 2017). After defining the success criteria, the metrics and KPIs to be tracked are established.

On the other hand, there is a distinction being made from Project Management success to project success (Wit, 1998 as cited in Sanjuan & Froese, 2013). The better the Project Management practices are, the better the results of the project will be (Sanjuan & Froese, 2013).

Stakeholders use the metrics to stay informed about the status of the project as well as helping them to monitor the maturity of the organisation regarding Project Management and the progress of the innovation (Kerzner, 2017). Using KPI metrics is a useful approach for performing these measurements.

KPIs allow decision-makers to get a real-time picture of the organization's operations, displaying the extent to which their objectives are being met (Sousa et al., 2018). The metrics and KPIs need to be set up for critical tasks which can directly impact on project success or failure, therefore assumptions and value tracking is essential (Kerzner, 2017).

The definition of project-specific metrics and KPIs are shared undertakings by the project manager, the stakeholder and the customer (Kerzner, 2017). Although it is difficult that the stakeholders agree on the metrics this should take place at the earliest possible stage in the project (Kerzner, 2017).

KPIs offer an objective means through which company activities and project success can be measured (Toor & Ogunlana, 2010). In addition, these metrics are an essential component of the organisation's strategy to forecast, measure and plan the business (Iuga et al., 2015)

Chapter 4 Lean Thinking

In this chapter, it is presented an overview about the background of Lean Thinking. It provides an in-depth study outlining the literature so far published in this field. It explores how the concept of Lean has progressively evolved, describing the main elements of this philosophy as well as the principles of Lean Thinking. In addition, a description of the main Lean tools, techniques and methodologies are also presented.

The term Lean has many interpretations as it has changed over the years. Lean is commonly related to its original former forms, which are Lean Manufacturing or Lean Production (Papadopoulou & Özbayrak, 2005). Nowadays it has a holistic application and it is used across a variety of sectors (Womack & Jones, 2003) and generally involves optimisation of the value stream through process continuous improvement (Sundqvist et al., 2017). This gives rise to its broad development from Lean Manufacturing to Lean Thinking.

> ***"Lean is a dynamic process of change, driven by a set of principles and best practices aimed at continuous improvement."***
>
> *Womack et al. (1990)*

Lean Thinking is a way of thinking, a value-based mind-set that includes principles, methods, and tools. Womack et al. (1990) defined Lean as a "*dynamic process of change, driven by a set of principles and best practices aimed at continuous improvement*" (Womack et al., 1990 as cited in Albliwi et al., 2015).

Lean is also described as *"an integrated socio-technical system, comprising a package of management practices that can be applied to eliminate waste and reduce variability of suppliers, customers and internal resources and processes"* (Mostafa et al., 2020; Shah & Ward, 2007). This approach relies on improving continuous flow, client-oriented production, eliminating waste, reducing defects, visual management, safe and clean working conditions, removing activities that do not add value but generate costs, and providing value to the client (Anholon & Sano, 2016).

Lean has been considerably popular and effective, leading to its implementation around the world in multiple sectors, such as construction, healthcare and manufacturing (Mostafa et al., 2020). This approach underwent further development over the last few decades, resulting into major shifts concerning the objectives, the scope, and the implementation methods. (Hines et al., 2004). Lean's success throughout manufacturing has inspired the adoption of this philosophy in

other industries (Hines et al., 2004). Furthermore, these Lean principles and ways of thinking continue to be extended beyond operations outside of the workshop.

4.1 Lean Evolution

Lean was originally launched as a methodology for industrial manufacturing with the goal of eliminating waste and continuously improving (Papadopoulou & Özbayrak, 2005). The Lean approach was influenced from Toyota Production System (TPS) (Womack et al., 1990). In 1987 James Womack coordinated a five-year study, conducted at the Massachusetts Institute of Technology (MIT) International Motor Vehicle Program, which analysed the performance of American, Japanese, and European automobile manufacturers, specifically Toyota's business processes (Anholon & Sano, 2016). John Krafcik, a team member, was the one who coined Lean as a term to designate the process of creating more value with less, reducing the use of overall components with respect to the mass production. The results of this research were published as a book by James P. Womack, Daniel T. Jones, and Daniel Roos in 1990 under the tittle of "*The Machine that Changed the World*" (Anholon & Sano, 2016).

Lean became popular in western countries due to the book publication (Anholon & Sano, 2016). The authors wrote about the way of Toyota management and how it operated. They were convinced that Lean was not only about cars and for Japan

(Womack et al., 1990). The book provided the first written data focusing on Japanese success.

After the success of *The Machine that Changed the World* book, the same authors also wrote another book called *Lean Thinking*. It sets out the principles to be followed by organizations in order to implement Lean and asserted that this approach could be applied in any industry and by anyone (Womack & Jones, 2003). This is when this way of thinking began to be called "Lean Thinking".

In 1997, the Lean Thinking gurus, James P. Womack and Daniel T. Jones, founded the Lean Enterprise Institute and Lean Global Network. This is a worldwide non-profit network of institutions that aim to bring Lean Thinking & Practice to different countries (Lean Global Network, 2021). The association define Lean Thinking & Practice as *"Systematically develop people and continuously improve processes to provide value and prosperity while consuming the fewest possible resources" (Lean Global Network, 2021).*

Lauri Koskela was the first to address the construction industries to explore and embrace Lean principles and techniques. Subsequently, about 1993, the first conference of the International Group for Lean Construction (IGLC) was organized in Helsinki. In this conference the term "Lean Construction" was coined (Ballard & Howell, 2003). Nowadays the IGLC is widely recognised with its main area of focus on developing theories of production and management with projects.

In the last few years, the fast-paced of the innovation has changed significantly. Businesses are recognizing the advantages gained from combining the Lean approach and Industry 4.0, which is called Lean 4.0 (Ozkeser, 2018).

Figure 5 outlines the key events and facts that influenced the evolving concept of Lean.

1880	Taylor	Taylorism, Work Scientific Management.
1927	Henry Ford	Mass production, functional departments, division of labour. Principles of the Ford Production System (FPS).
1937	Kichiro Toyoda	Just in Time (JIT).
1950	Ohno, Shingo	Toyota Production System (TPS), the seven wastes.
1950	E. Deming	PDCA
1960	Eiji Toyoda	Total Quality Management methodology (TQM). Toyota systems applied to vehicle assembly.
1973		Oil crisis in the United States triggers great interest in Japanese manufacturing and management practices.
1981	Ohno, Shingo	First English Toyota systems literature available.
1986	Motorola	Six Sigma, DMAIC methodology.
1988	John F. Krafcik	The term Lean is coined to describe the manufacturing system used at Toyota.
1990	Womack, Jones & Roos	Lean Production. *The Machine That Changed the World* book publication.
1993	Lauri Koskela	Lean Construction term. Foundation of the International Group for Lean Construction (IGLC).
1993	Ballard & Howell	Last Planner System (construction projects context).
1994	Womack & Jones	*Lean Thinking* book publication. The Lean principles and philosophy are extended to an enterprise level.
1997	Womack	Lean Enterprise Institute, Inc. (LEI), founded by James P. Womack.
1999	Ballard & Howell	Lean Project Management.
1999	Naylor et al.	LeAgile concept in paper publication.

2000	Ballard & Howell	Lean Project Delivery System (LPDS).
2001		Agile Manifesto
2003	Poppendieck & Poppendieck	Lean Software Development.
2011	Eric Ries	Lean Startup ("The Lean Start up" book) New business or product strategy.
2011		Lean 4.0 is the combination of lean and Industry 4.0.

Figure 5: Timeline plotting the key stages of Lean evolution (Source: inspired on Hines et al., 2004; Shah & Ward, 2007)

4.2 Lean Philosophy

"The lean ideal is to deliver customer value without waste" (Salgin et al., 2016). For most of the reviewed publications, the main focus is on the systemic approach of Lean requiring the deployment of the whole system to obtain the full impact of Lean (Hines et al., 2004). Therefore, this approach is applied as a strategic way of integrating all processes and operations into a system to provide a

> ***"Lean is applied as a strategic way of integrating all processes and operations into a system to provide a better service to the customer, removing the waste by means of continuous improvement"***
>
> *Mostafa et al (2020)*

better service to the customer, removing the waste by means of continuous improvement (Mostafa et al., 2020).

The mere use of Lean tools is often wrongly considered as Lean. Lean appears as a philosophy more than just as a collection of tools used for improvement (Hines et al., 2004; Womack & Jones, 2003). The universality of Lean is described by many authors as being based on the principles more than on the tools and techniques (Hines et al., 2004; Langstrand & Drotz, 2016)

Nevertheless, there are several aspects of this approach which are directly linked to each other. The work of (Shah & Ward, 2007) provides an operational and technical point of view. On the other hand, Hines et al. (2004) state that the level of strategy is concerned with the creation of value and comprehension about the value added to the customer, while the level of operations deals mainly with the improvement of the efficiency and minimization of costs.

Langstrand & Drotz (2016) described three dimensions of Lean: the technical, rhetorical, and organizational. At the technical level it includes Lean methods and techniques. Regarding the rhetorical aspect, it covers Lean principles, goal formulations and expected outcomes from applying Lean. Thirdly, is the organizational dimension which involves concepts such as work organization and division of responsibilities (Langstrand & Drotz, 2016).

The Toyota model has been considered as a benchmark by a large number of organisations when it comes to implementing the Lean. This model acknowledges that organisational culture is a crucial factor in the implementation of lean or any other quality system (Al-Najem et al., 2012). In addition, for the correct development of Lean, team work, team motivation, problems solving, effective communication and cultural change are essential aspects (Mostafa et al., 2020).

The research by Al-Najem et al. (2012) leads them to the finding that lean management is mainly philosophical more than technical. According to Liker (2004) the culture of a lean system consists of an external part, starting with the customers, and another internal part which begins with respect for people and the continuous improvement of the internal culture (Al-Najem et al., 2012). These levels of Lean application are outlined in Table 3.

Table 3: *Levels of Lean application (Source: Author)*

Lean levels	**Concepts**	**Source**
Technical	Methods, techniques. key strategic drivers and enablers top-down approach shared vision setting economic goals	Langstrand & Drotz (2016)

Rhetorical / Tactical	Overall Lean principles, goal formulations and expected outcomes. learning and training transformation of the vision into reality	
Organisational culture	respect for people long-term vision continuous improvement solve problems collectively make decisions based on facts	(Al-Najem et al., 2012) (Liker, 2004)

4.3 Lean Principles and Concepts

Lean thinking enables companies the opportunity to identify value, to align the actions of value creation according with optimal workflow, to carry out such activities uninterruptedly on demand, and execute them with enhanced effectiveness (Cruz-Villazón et al., 2020). Womack and Jones (1996), with the Lean Thinking they proposed a five-step process known as Lean Principles (Figure 6) (Lean Enterprise Institute, 2021). These principles are a guide, focus on value and waste elimination, applicable to any company or organisation, across all sectors and (Hines & Taylor, 2000; Sousa et al., 2018).

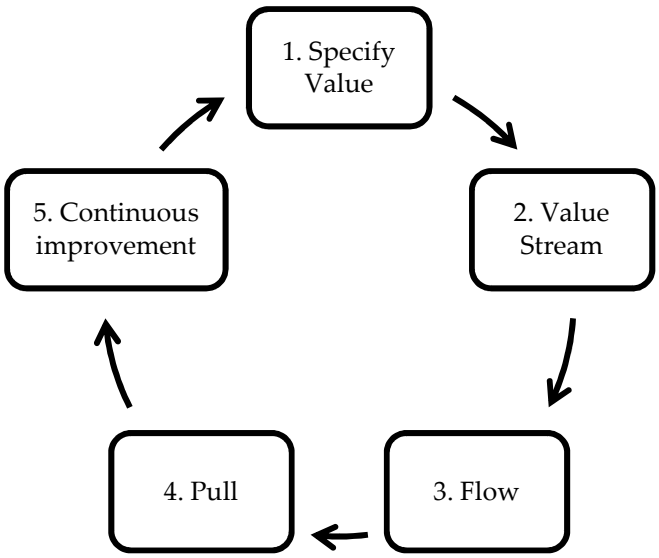

Figure 6: Lean Thinking Principles (Source: Womack & Jones, 2003)

Specify Value: Define everything that adds value from the perspective of the customer (Hines & Taylor, 2000). The important requirements or expectations to be fulfilled are specified. This drives towards defining the value in either a product or a service that satisfies the needs of the customer (Womack & Jones, 1997).

Value Stream: Identify every single activity, throughout the entire value stream, detecting those activities contributing to add value to the customer. Eliminate all that does not provide value according to the perspective of the customer (Hines & Taylor, 2000).

Flow: Make value-creating actions flow with no disruptions, deviations, backtracking, waiting or any form of waste (Hines & Taylor, 2000).

Pull: Focuses on pulling value out of previous business activities while initiating flow (Lean Enterprise Institute, 2021). According to Tyagi et al. (2015) (as cited in Mostafa et al., 2020), Lean approaches target on pulling with the aim of preventing overproduction of material by targeting the correct customer at the exact time (Mostafa et al., 2020). The Pull principle turns the process into a demand-driven system. This means that any good or service does not have to be generated until the next customer in the value stream demands it.

***Continuous improvement*:** Strive towards perfection through continuous elimination of waste as it is being detected (Hines & Taylor, 2000). Lean continuous improvement aims for perfection by eliminating Muda (meaning waste), making it possible for each activity in the entire value stream to create value (Womack & Jones, 1997). This reduces team overload and prevents process inefficiencies that directly impact the performance.

4.3.1 The Concepts of Value and Waste

> ***"Lean management is based upon values."***
> *Reusch & Dechange (2013)*

The concept of value is the central focus of Lean. As defined by (Reusch & Dechange, 2013)"Lean management is based upon values". The implementation of Lean concepts enhances the workflow by minimizing delays, rework or recurring wastes. The focus of Lean is to increase customer value,

either internal or external, along the complete value chain (Simon & Canacari, 2012). Value must be defined from the customer's standpoint and in terms that are meaningful to them.

Lean standpoint customers are: stakeholders; the whole customer organisation such as the payer, the user, among others; the next in the process; the society and the planet (Womack & Jones, 2003). The analysis of value drives out the costs and values associated with the processes as well as the products (Reusch & Dechange, 2013). Furthermore, it also strives for less costly and value adding alternatives for customers (Reusch & Dechange, 2013).

> ***"Lean standpoint customers are: stakeholders; the whole customer organisation such as the payer, the user, among others; the next in the process; the society and the planet"***
>
> *Womack & Jones (2003)*

Value are the enablers allowing the customer to reach their goals, these are the means towards those ends. Whereas, waste refers to anything that carries a cost in any form financial, stress and environmental impact which can be removed without decreasing the value added (Womack & Jones, 2003).

Bicheno & Holweg (2016) include stakeholders as customers and emphasize the impact of reducing resources (materials, energy, and pollution) to achieve sustainability. According to (Bicheno & Holweg, 2016) Lean's continuous improvement is performed along three axes:

Value → enhancement

People → involvement

Waste → reduction

By eliminating waste in the process, value is increased and consequently cost, quality, and delivery time can be improved by focusing the efforts on activities of true added value (Simon & Canacari, 2012). Bicheno & Holweg (2016) described value as an elusive asset that needs to be continuously adapted and refined.

Gemba is a Japanese word used in Lean that means "where value is created" (Simon & Canacari, 2012). A key aspect of Lean troubleshooting is the use of direct observation of the workplace where operations are being performed.

For the customer standpoint, those are the instance of value creation when something is being done to their product, good or service that is going to help them in their life (Womack & Jones, 1996).

According to the Lean perspective, there are three types of activities:

Value-added (VA) activity: these activities make a product or service more valuable from the customer's point of view. These activities should be maximized (Hines & Taylor, 2000).

Necessary Non-Value Added (NNVA) activities: the Japanese call them "Non-Value-Creating Work" (Shook, 2018) and they are also referred as Value-

Enabling activities or “incidental work” (Womack & Jones, 1997a). These are the activities used to design and to organize work. The better this type of work is managed, more waste can be eliminated, and value can be maximized (Shook, 2018). These activities are difficult to remove on a short-term basis and therefore need to be subject to a radical or long-term change (Hines & Taylor, 2000).

Non-Value Added (NVA) activities: activities known as “muda”. Activities that, according to the point of view of the customer, they are not adding value into a product or service being delivered. These actions are considered "waste" and should be eliminated as soon as possible (Albliwi et al., 2015)

Based on the literature it is possible to summarize the way value is defined from the Lean perspective as shown in the following table (Table 4):

Table 4: *Description of Lean value (Source: Author)*

Type of value	**Features**	**Waste**	**Action**
Value of processes and activities	VSM Waste	Material, information, human resources, time, effort	Identify areas for improvement. Waste identification. Detect non-value-added activities.
Perceived value by the customer	VoC QFD	Non-value-added aspects	Requirement compliance. Involvement of customers.

Waste in Lean means all factors that constrain a business from reaching a fully efficient production system (Pieńkowski, 2014). From a Lean perspective, the types of wastes can be classified into three categories, namely: Mura (inequality, inconsistency), Muri (overload) and Muda (uselessness). These three are related among themselves and together they determine the concept of waste (Pieńkowski, 2014). Table 5 describes the seven types of waste considered as Muda.

Table 5:*Lean types of waste (Source: Hines & Taylor, 2000).*

Type of waste	**Description**
1. Overproduction	To produce either too much or too early, leading to a bad flow of information or goods and excessive inventory.
2. Defects	The frequent paperwork errors, problems with product quality or deficient performance being delivered.
3 Inventory	Over-storage and delay of information or products, leading to too much cost and bad service to the customer.
4 Over processing	Carrying out work processes employing incorrect tools, or procedures, or even systems.
5 Transportation	A high turnover of people, information or goods leading to lots of time, wasted effort and costs.
6 Waiting	Extended inactivity time spent by people, or information and goods, causing inefficient flow and delays in delivery times.
7 Motion	Improper organisation of the workplace, which results in incorrect ergonomics, such as frequent bending or stretching and misplacement of objects.

Recently, two additional forms of waste are emerging in the literature, which are the under-utilisation of human creativity and the environmental waste (Vinodh et al., 2012 as cited in (Albliwi et al., 2015).

4.3.2 Lean Tools and techniques

The concept of Lean encompasses a broad set of practices, methods, and tools. Significant attempt has been spent in consolidating a comprehensive description of those, yielding as a result a set of toolkits identified through the review of the literature. Below in Table 6 these insights are listed along with a brief description.

Table 6: *Lean Tools and Techniques (Source: Cruz-Villazón et al., 2019)*

Tools and techniques	**Description**	**References**
5S	Focuses on effective workplace organization and standardized work procedures.	Abdulmalek & Rajgopal (2007); Sugimori et al., (1977); Womack & Jones (1996)
A3	A visual method for communicating only pertinent information like proposal, problem solving, status reporting and competitive analysis.	Liker & Morgan (2006); Moreci (2014)

Andon	The use of visual controls, such as overhead displays or electronic dashboards, to briefly convey the status quo of the work.	Liker (2004), Ohno (1988); Womack & Jones (1996)
Cross-Functional Teams	The aim is to have team members who are able to perform different tasks in order to increase flexibility and reduce variability and risk exposure.	Shah & Ward (2003); Sugimori et al., (1977)
Genchi Genbutsu	Encourages workers, team leaders, and executives to go to the *Gemba* (the place in reality), to inquire a problem directly and work collectively on a solution	Liker & Morgan (2006)
Heijunka	Aims at levelling, because when the workload is levelled, there are opportunities for standardized processes.	Liker (2004); Ohno (1988); Sugimori et al., (1977); Womack & Jones (1996)
Hoshin Kanri	A method for ensuring that the strategic goals of a company drive progress and action at every level, aiming to eliminate the waste that comes from inconsistent direction and poor communication	Liker (2004); Womack & Jones (1996)
Jishuken	A method of gathering managers for problem solving in the production process and continuous improvement	Marksberry et al. (2010)

JIT	Just-In-Time (JIT) concentrates on producing the right product at the right time.	Ohno (1988); Sugimori et al., (1977); Womack & Jones (1996)
Kaizen	An approach for continuous improvement, where Daily *Kaizen* acts as a daily activity.	Liker (2004); Ohno (1988); Womack & Jones (1996)
Kamishibai Boards	A visual control for performing internal audits of processes or systems, aiming to train people to understand problems and find possible improvements.	Niederstadt (2013)
Kanban	A way to communicate between processes through a signalling system to help implement a pull system and to achieve a continuous flow.	Abdulmalek & Rajgopal (2007); Sugimori et al., (1977); Womack & Jones (1996)
Obeya Room	A system that provides dedicated space, as well as time, for coordination and problem-solving, designed to minimize organizational barriers.	Liker & Morgan (2006)
PDCA	PDCA (Plan, Do, Check and Act) is an iterative methodology to propose a change in the process, implement it, measure the results and take appropriate action.	Moen & Norman (2006)
Poka-Yoke	Meaning "mistake-proofing" encourages the use of a range of low-cost, highly reliable devices	Liker (2004); Ohno (1988)

	throughout the different processes to prevent defects.	
Root cause analysis	An iterative interrogative technique used to explore the cause-and-effect relationships underlying a particular problem (e.g. 5 Whys, Ishikawa Diagram).	Liker (2004); Ohno (1988); Womack & Jones (1996)
Standardized Work	Setting a standard and bringing a condition into conformance with that standard, makes it possible for everyone to know what to do and when to do it.	Liker (2004); Ohno (1988)
Supplier Involvement	A form of vertical collaboration with the suppliers to ensure alignment and accountability throughout the project cycle.	Liker (2004); Womack & Jones (1996)
Teamwork	Building strong teams facilitates initiatives, which enables more consistent working and the elimination of waste.	Liker (2004); Ohno (1988); Womack & Jones (1996)
TQM	Total Quality Management (TQM) is a system of continuous improvement that employs participative management techniques centred on the needs of customers. Key components are employee involvement and training, problem-solving teams, statistical methods, long-term goals, and recognition that inefficiencies are produced by the system, not people.	Abdulmalek & Rajgopal (2007); Shah & Ward (2003)

Value stream mapping	This approach intends to visually map the actual and future state of processes to highlight opportunities for improvement.	Abdulmalek & Rajgopal (2007); Womack & Jones (1996)
Visual Controls	Visual indicators, displays, dashboards or controls used to improve communication of information, by making it easily accessible and clear, to everyone.	Liker (2004); Ohno (1988)

Chapter 5 Lean Project Management

This section explores the main features relevant to Lean Thinking in Project Management. Here, it is presented an exhaustive analysis of the information gathered on Lean Project Management as an integrated concept. SLR is conducted with the objective of investigating the origins, trends, contributions and gaps in research on the subject. The use of Lean in project-based organizations is discussed and the application within different sectors is closely analysed. Since the central theme of this thesis concerns the application of Lean Project Management for the identification of performance indicators, the concepts involving KPIs, indicators, metrics for measuring performance and project-related success factors are also investigated.

Lean Project Management is the application of Lean principles, tools, and methods to the discipline of Project Management. In this chapter it is presented a comprehensive analysis of the information gathered concerning this topic. First, an in-depth literature review is made through using the SLR previously described in Chapter 2 Followed Methodology. The main purpose of the Lean Project Management

SLR is researching the origins, trends, contributions, and gaps in Lean Project Management research as a concept.

Following the Descriptive Analysis, detailed descriptions of the content covered by the studies are provided. These include theoretical and conceptual background on Lean applied to projects and Project Management, Lean Project Management principles and the Lean Project Management focus on value and waste. Moreover, the techniques, methodologies, and tools of Lean in Project Management are also discussed.

Furthermore, this section also explores the use of Lean in project-based organizations together with a deeper insight on its application within the relevant sectors. As the core theme of this thesis concerns the application of Lean Project Management for the identification of performance indicators, the concepts involving KPIs, the relevance of indicators, metrics for measuring performance, and success factors as they relate to projects are also investigated.

5.1 SLR of Lean Project Management

The SLR process continue with the analysis of the 103 publications selected. This step was performed by means of a descriptive analysis followed by a synthesis of the information collected.

The variables used for the descriptive analysis were the relation of the number of publications per year; by the countries where the studies were carried out; the authors; the nature of the publication; the methodology and the contributions. The publications identified in this SLR that were selected to be included in the analysis in this section are shown in the following Table 7.

Table 7: *Parameters and metrics for the analysis of the selected literature review (Source: adapted from Oliveira et al., 2019)*

Data	**Parameters**	**Metrics**
Year of publication	Evolution of publications	Number of publications per year
Research sector	Most searched sector	Number of publications per sector
Methodology	Most applied research methodology	Type of methodology used for each paper
Type of paper	Percentage of the type of paper	Number of theoretical and empiric papers
Keywords	Most frequently used keywords	Number of keywords
Article title	Most cited articles	Citation index
Authors	Most cited authors	Citation index
	More productive authors	Number of publications per author
Institutions	More productive institutions	Total of publications of the institutions

Periodicals	Distribution of publications (journals, conferences) More productive journals, conferences	Total of publications per periodical Number of publications per periodical
Country of research	More productive countries	Number of publications per country

The complete table containing all the data collected from bibliographic analysis of the papers selected for inclusion in this study is provided in Appendix A. The table in the Appendix B displays the information concerning the publications on Lean and its application in the organizations and their type of sector. In addition, it indicates the specific Lean approach, tool and principle discussed in each of the documents (Appendix C). Moreover, it identifies which papers include a reference to performance indicators.

5.1.1 Descriptive Analysis

The descriptive analysis was performed using the literature referring specifically to Lean Project Management. This is due to the fact that the main focus of the thesis was to explore on the application of the Lean approach to Project Management. The descriptive analysis was conducted using as a baseline the 103 papers (Appendix A) selected from the SLR after applying the inclusion criteria. The

content of these publications is referenced thoroughly in Chapter 5 Lean Project Management.

For the analysis of paper types, the classification proposed by (Panayiotou & Stergiou, 2021). It consists of six different categories, as described below:

Research paper: Research conducted by the authors, survey or framework applied to analyse results and make inferences.

Case studies: Describe actual interventions or experiences in organizations.

Literature review: Review and discuss the literature related to the research topic.

Point of view: Content is based on the author's opinion and interpretation.

Conceptual paper: It is a study that develops hypotheses.

Technical paper: Describes and assesses products, processes, or technical service.

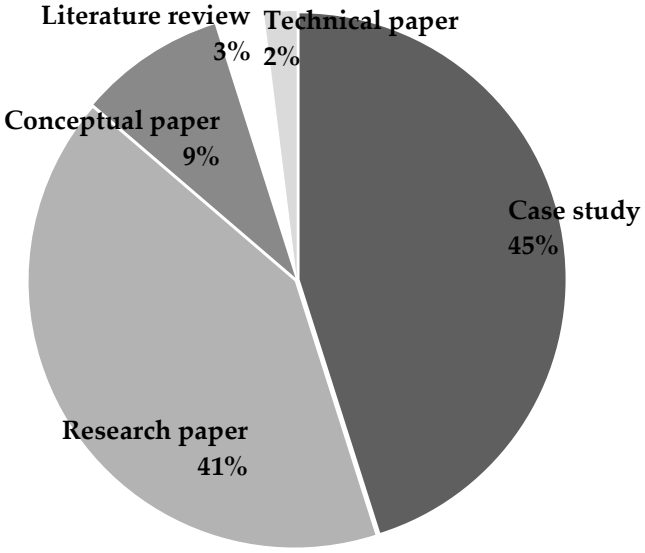

Figure 7: Percentage of paper types based on the Panayiotou & Stergiou (2021) classification

According to the classification of paper types (Panayiotou & Stergiou, 2021), the percentages shown in Figure 7 were obtained. Most of the publications are mainly Case Study analysis (45%), although very close are the Research Papers type (41%) in which the authors performed surveys or frameworks applied to analyse results and to make deductions. Conceptual Papers (9%), Literature Reviews (3%) and Technical Papers (2%) appeared relatively weak among the selected documents.

The data collected was screened to identify recurrent themes, ideas, gaps, etc. The selected literature was examined according to different parameters. In order to track the evolution of the Lean Project Management concept over the years, the year of publication of each published article was taken into account (Table 8).

Table 8: *Number of Lean Project Management publications per year (Source: Author)*

Year of publication	No. of papers
1993	1
1997	1
2000	1
2003	1
2006	1
2007	4
2008	4
2010	3
2011	4
2012	8
2013	7
2014	8
2015	6
2016	6
2017	7
2018	7
2019	12
2020	11
2021	10

This parameter of evolution allowed to identify the trend of the publications, indicating how extensively this topic has been researched or whether there is a

decrease of interest from the scientific community (Oliveira et al., 2019). Figure 8 shows the publications on Lean and Project Management per year.

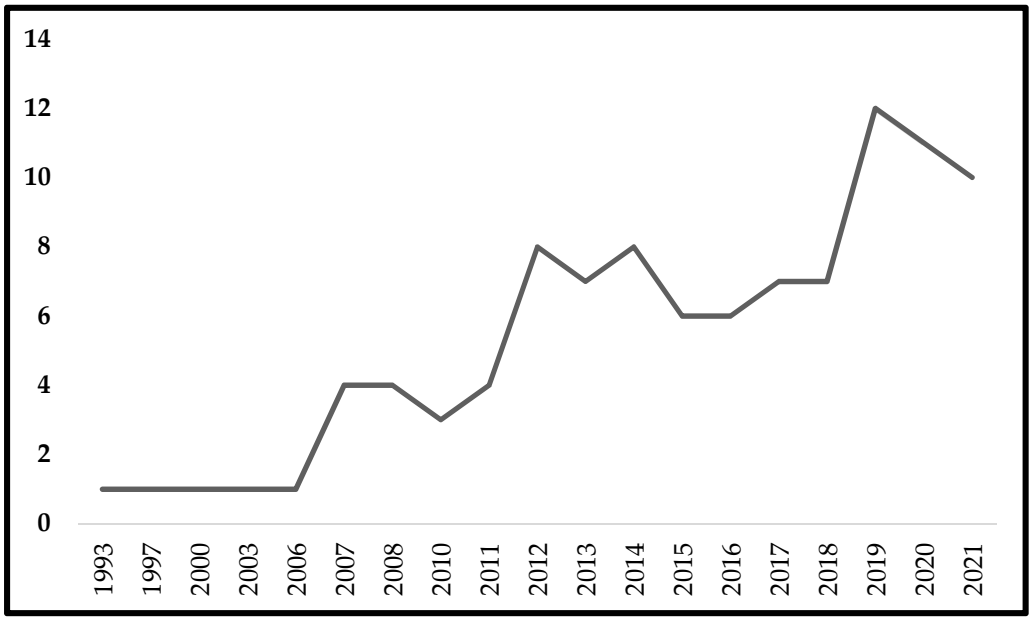

Figure 8: Distribution of Lean applied to Project Management publications over the years (Source: Author)

The graph in Figure 8 was elaborated with the information presented in Table 8 Bibliographic Analysis about Lean in Project Management. What stands out in is a significant increase in the number of papers published since 2003. The results clearly reflect that the topic of Lean Project Management gained significant interest and popularity within the research community over the last 15 years, most of the publications were issued between 2007 and 2022.

It shows the positive trend concerning the level of interest for conducting research on Lean Project Management. The chart also illustrates that the first papers discussing this topic were published in the early 1990's. These were the contributions of Riis, J.O. (1993) and Gabriel, E. (1997) published in the *International Journal of Project Management*. It is worth noting that these two articles correspond in timing with the launching of Womack's book *"The Machine that Changed the World"*.

After these publications, it can be seen in the graph that for the next ten years, the number of papers published was very scarce until Ballard and Howell from the university released their investigations concerning LSP (Ballard & Howell, 2003). Their concepts linking Project Management practices with the Lean approach transformed the way projects were delivered in the Construction sector. Their work is widely referred by numerous researchers.

To determine the relevance of the references, it was considered the frequency of citing of the source in the selected databases for data capture. Table 9 lists the obtained results of the 30 most cited sources. The first column contains the name of the source and in the second column the number of times cited.

Table 9: *Number of Lean Project Management publications per year (Source: Author)*

Source	Cited	Source	Cited
Ballard & Howell (2003)	518	Chen et al. (2007)	36
Verrier et al. (2013)	229	Lee et al. (2010)	34
Simon & Canacari (2012)	159	Sertyesilisik (2014)	30
Tenera & Pinto (2014)	150	Uusitalo et al. (2019)	24
Howell & Koskela (2000)	144	Hozak & Olsen (2014)	22
Sunder (2016)	111	Ansah et al. (2016)	21
Sohi et al. (2016)	100	Abuhejleh et al. (2016)	20
Brioso (2015b)	79	Dallasega et al. (2020)	20
Gabriel (1997)	76	Kemmer & Koskela (2012)	20
Ximenes et al. (2015)	52	Fitzgerald et al. (2014)	36
Bryde & Schoolmaster (2013)	49	Reusch & Reusch (2013)	34
Elias (2016)	39	Herrera et al. (2020)	30
Sreedharan & Sunder (2018)	39	Sousa et al. (2018)	24
Deshpande et al. (2012)	38	Anholon & Sano (2016)	22
Brioso (2015a)	36	Chen (2012)	21

Table 9 shows that the publication by Ballard & Howell (2003) heads the list (518 citations) of the sources on Lean Project Management most frequently cited. The reason behind it can be explained due to the fact that the Last Planner System (LPS) methodology developed by these authors was released in that publication. Subsequently they founded the Lean Construction Institute following the

recommendation of the construction industry which had previously profited by working with the LPS.

In second place (229 citations) follows Verrier et al. (2013) with their publication in the Journal of Cleaner Production which touches on the topic of Lean projects focused on sustainability. This is followed by the works of Simon & Canacari (2012) and Tenera & Pinto (2014) with a slight difference in the number of citations (159 and 150 respectively). The first authors published a practical guide for the application of Lean tools in projects in the Health Care sector. The other authors released a model which they developed on Lean Six Sigma (LSS) for project management improvement.

Another important contribution is Howell & Koskela (2000), which ranks fifth in Table 9, with 144 citations. In this publication, the authors explain the innovative concept of Lean Construction and its role in project management.

The selected publications are from both conferences and journals almost equally distributed in terms of number of issues. Appendix B and Appendix C list the names of the conferences and journals that published these papers. By calculating the total number of papers from each of the sources, 54 were published in conferences and 51 in journals, representing 51% and 49%, respectively, of the total literature reviewed Figure 9.

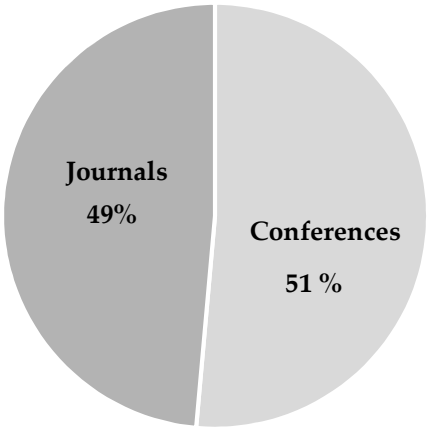

Figure 9: Percentage of Lean Project Management publications in conferences and journals (Source: Author)

Table 10 enumerates the sources, both journals and conferences, in which the most publications on Lean Project Management were located. It is observed that the highest concentration of published papers was in the Annual Conference of the International Group for Lean Construction (13). It is possible to infer the reason behind it is that the main focus of this conference is on projects within the construction sector using the Lean approach. This conference is organized by The International Group for Lean Construction founded by Greg Howell and Glenn Ballard in 1997. The relevance of the IGLC lies in the fact that in this institution the term Lean Construction was coined.

Several papers published in different conferences organized by the IEEE appear. For this reason, it is in the second position with 7 publications. Table 10 includes two of the most recognized journals on Project Management, the

International Journal of Project Management (with 5 papers) and the Journal of Modern Project Management (with 2 papers). Thus, the application of Lean in the management of projects is a topic being researched within the Project Management community.

Table 10: *Sources and frequency of publication of Lean Project Management papers (Source: Author)*

Source of publication	**Abbreviation**	**Frequency**
Annual Conference of the International Group for Lean Construction	IGLC	13
Institute of Electrical and Electronics Engineers (Conferences)	IEEE	7
Journal of Modern Project Management	JMPM	5
Advanced Materials Research	AMR	3
International Conference on Construction & Real Estate Management	ICCREM	2
Procedia-Social and Behavioral Sciences	PSBS	2
Academy of Management Review	AMR	2
Buildings	Buildings	2
International Journal of Lean Six Sigma	IJLSS	2
International Journal of Project Management	IJPM	2
Journal of Cleaner Production	JCP	2
Sustainability	Sustainability	2

Providing an overview of the regions where more research is being carried out regarding Lean Project Management concepts, the nationalities of the authors of the selected publications were extracted from Appendix A.

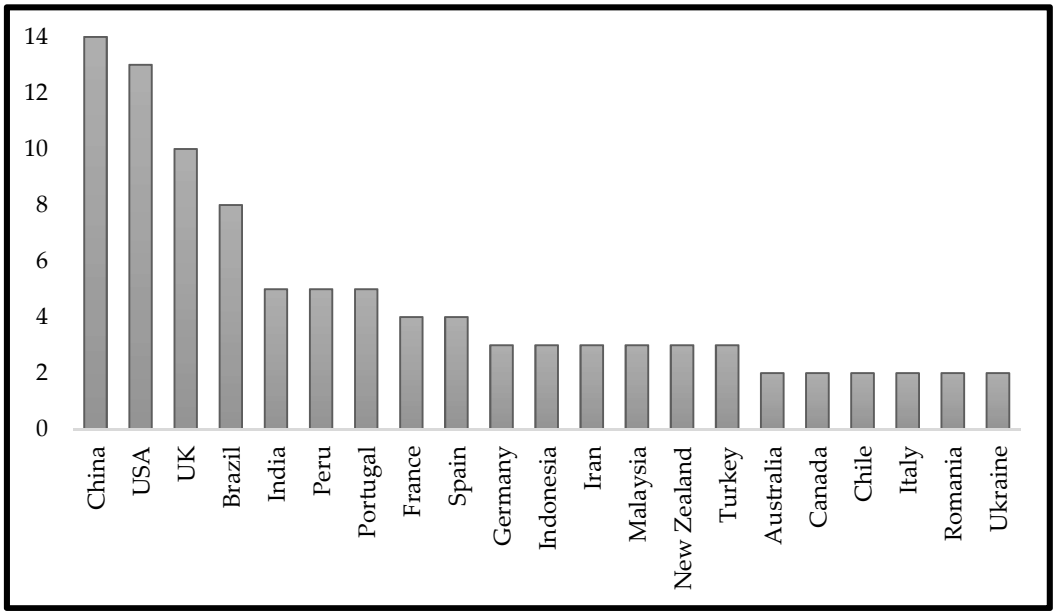

Figure 10: Country of origin of Lean Project Management publication researchers (Source: Author)

The following chart (Figure 10) reveals at a glance that researchers from China and the United States of America (USA) are the most active contributors to Lean Project Management research. They are followed very slightly behind by researchers from the United Kingdom (UK) and Brazil. Analysing all these data together, can be observed that the vast majority of countries are European (UK, Portugal, France, Spain, Germany, Italy and Romania). American countries such as USA, Brazil, Peru, Canada, and Chile follow in number.

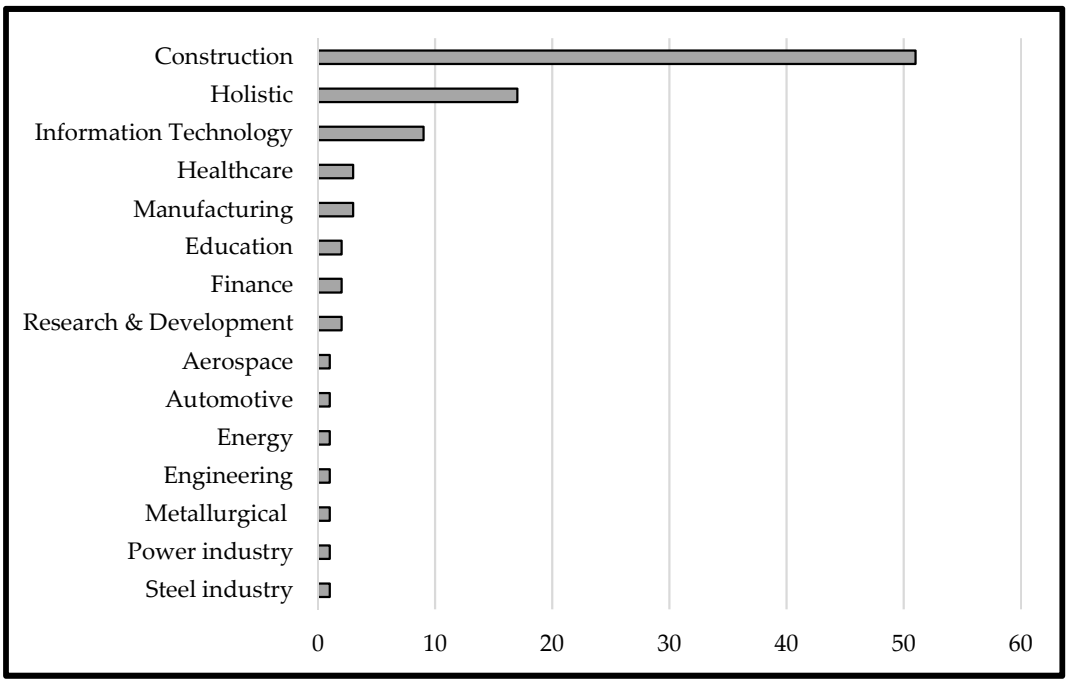

Figure 11: Percentage of publications on Lean Project Management in the different sectors (Source: Author).

Figure 11 represents the percentage of publications on Lean Project Management in the different sectors. The information provided by this chart enables to see in which fields more research efforts have been focused and which remain unexplored. As can be seen, the majority is within the sector of Construction (53%). Then a large percentage (18%) belongs to research done holistically. Other important branch in which the application of Lean and Project is researched is Information Technology with 10%.

5.1 Theoretical background of Lean Project Management

New trends of change are coming to the management of projects. Old approaches to Project Management are not sufficient to deal with the current and future projects (Kerzner, 2017). Project Management concepts, methods and instruments are being reinforced through the integration of quality disciplines such as the Lean approach (Reusch & Dechange, 2013). Although Lean may not be a particularly novel approach, the concept offers an innovative implementation focus for company-related issues (Dursun et al., 2019)

> ***"The evolution of Project Management will lead to Lean Project Management"***
>
> *Reusch & Dechange (2013)*

Through continuous experimentation, employees and leaders learn to achieve higher quality and better flow, reduced time and effort, and less cost (PMI, 2022). Such continuous and systematic learning comes as a consequence of a Lean way of thinking and practising (PMI, 2022). Reusch & Dechange (2013) stated in their research that "the evolution of Project Management will lead to Lean Project Management."

Reusch & Reusch (2013) argue that "*lean management is a management of values*" and which is applicable for improving Project Management (Cruz-Villazón, 2018). Their paper quotes Stephan Wood, stating that "*Quality Management means Lean*

Management". Quality Management principles (ISO 9000) such as costumer focus, continual improvement, and process approaches, are, among others the bases of lean management (Reusch & Reusch, 2013 as cited in Cruz-Villazón, 2018). This is crucial for linking Lean to Project Management since Quality Project Management is one of the PMBOK's Project Management ten knowledge areas (Cruz-Villazón et al., 2019)

Research on Lean Project Management as a concept can be traced back to more than two decades. Gabriel (1997) wrote for the International Journal of Project Management the article "Lean Project Management". He provided an early definition of the term Lean Project Management by illustrating through case studies on complex construction projects the development of this practice (Cruz-Villazón et al., 2019). The Lean Project Management approach of his research yielded to a significant level of team commitment and motivation, as well as customer satisfaction throughout the client's organization. Furthermore, his work explains how Lean Project Management leads towards project success, fulfilling the criteria of quality, timing, and budget.

> ***"Projects are temporary production systems. When those systems are structured to deliver the product while maximizing value and minimizing waste, they are said to be 'lean' projects."***
>
> *Ballard & Howell (2003)*

Ballard & Howell (2003) in their research on Lean Project Management they state that *"projects are temporary production systems. When those systems are structured to deliver the product*

while maximizing value and minimizing waste, they are said to be Lean projects. Lean project management differs from traditional project management not only in the goals it pursues, but also in the structure of its phases, the relationship between phases and the participants in each phase" (Ballard & Howell, 2003).

Ballard & Howell (2003) pointed out the need to develop theory as well as rules and tools to manage project-based production systems. As a result of this gap, out of theoretical and practical investigations they developed the Lean Project Delivery System (LPDS). The LPDS implements the principles and tools of Lean through the whole project lifecycle of construction project.

Lean Project Management embraces Lean Thinking mind-set to execute a project in a more efficient way in order by delivering customer value. According to (Horman & Kenley, 1996), Lean Project Management employs the efficiency strengths of Lean and the effectiveness efforts from the Project Management to improve the performance within the management of projects. Nevertheless, it is crucial to understand in which way the principles of Lean should be used in Project Management processes and what existing synergies among themselves.

Ansah et al. (2016) and Ballard et al. (2007) pointed out that the Lean philosophy is a culture with application to any industry, business divisions, processes and even to projects (as cited in Cruz-Villazón, 2018). Eliminating inefficient processes

through Lean has been a popular business approach in which Lean tools are used to create efficient operations (Mostafa et al., 2020).

Sousa et al. (2018) through action-research conducted a study using Project Management practices in conjunction with Lean Thinking principles. The company they analysed had a growing number of new projects. Therefore, they implemented these two approaches in order to improve production processes and performance, consequently leading to a reduction in process bottlenecks as well as decreasing project delivery time.

5.1.1 Lean Project Management Principles

Several researchers have studied the application of Lean principles in Project Management. Aziz (2012) defines Lean Project Management attempts to address the management of projects in the direction of value creation and waste avoidance by improving the productivity of the project (as cited in Cruz-Villazón et al., 2019). The following table (Table 11) explains how they linked these the two approaches (Cruz-Villazón et al., 2019).

> ***Lean Project Management tends to focus Project Management toward creating value and preventing waste improving project's productivity.***
> *(Aziz, 2012)*

Table 11: *Lean principles applied to Project Management (Source: based on Bade & Hass, 2015; Barbero & Stira, 2013; Reusch & Dechange, 2013; Reusch & Reusch, 2013)*

Lean Principles	Lean Project Management Principles
Identify Value	• Identify value by determining objectives and requirements or problem to be solved. • Satisfy the customer and all stakeholders' needs.
Value Stream	• Map the workflow with the focus in the actions and people involved in the process. • Detect the parts of the process that add value and the ones that don't. • Identify where resources are overburdened, what impact risk, relationships and quality.
Flow	• Modulate the project flow towards the team's performance in function of its capacity of accomplishment. • Limit resource overload and reduce multitasking to a minimum. • Ensure that each project responds to a significant need. • Break up the work into small units to identify and handle roadblocks easily.
Pull	• Employ pull planning so that nothing is made or delivered until it is needed.

Continuous Improvement	• Endeavor to achieve perfection on a continuous basis to eliminate that which is not adding value within the process. • Make decisions at the right time. • See the whole.
Respect for People	• Involve the people in planning the process. • Enable people the ability to adjust the process, under well-defined conditions, according to the requirements of the context. • Make sure that staff members participate in the continuous improvement of each process. • Cultivate a human and supportive environment. • Train staff to evaluate processes in a systematic and critical way and to suggest possible improvements.

In addition to the Lean guiding principles mentioned above, the PMI includes other relevant Lean principles for managing projects, more specifically for knowledge work. The following listed are the eight guiding principles for lean thinking and practice (PMI, 2022): 1) Build quality in, 2) Eliminate waste, 3) Learn pragmatically, 4) Keep options open, 5) Deliver value quickly, 6) Respect people, 7) Optimize the whole, 8) Build in resilience.

5.1.2 Lean Project Management Value and Waste

Lean is value-based approach whereas for Project Management it is a rather recent development area (Reusch & Dechange, 2013). In a project context, the concept of value needs to be transformed into clear characteristics to make it a measurable and useful element for project's success. In projects, business value is the benefit delivered by the outcomes from a particular project to its stakeholders. A project's benefit can be either tangible, intangible or both (PMBOK, 2017). Managing values takes a further strategic approach to bring an organization into alignment in order to optimize customer value and shape processes (Reusch & Dechange, 2013).

The Lean approach enables project management to pinpoint both the value and the stream of value. The identification and elimination of wasteful activities in Lean Project Management are considered an opportunity for value creation (Moujib, 2007). Making the value stream visible to all team members is also an important factor in improving project efficiency. If the process is visualised by everyone, they can have a shared agreement between them and be fully informed about the role they are playing throughout the entire process. This is an empowering element to improve the efficiency of the project, increasing the motivation and positive thinking of the project participants (Moujib, 2007).

Lean Project Management is directly linked with the maturity level of the project management (Reusch & Dechange, 2013). The processes are optimised along

the lines of a maturity model when they meet a level of minimum waste according to Lean perspective (Reusch & Dechange, 2013). Several types of waste occur during the management of projects, as identified through a number of studies (Moujib, 2007; Reusch & Reusch, 2013).

Table 12 summarizes the seven types of waste in the context of Project Management which were found in the literature.

Table 12: *Waste in Project Management (Source: based on Barnero & Stira, 2013; Moujib, 2007; Reusch & Reusch, 2013; Stack, 2013)*

Type	*Waste*
Transportation	Inadequate distribution of the workplace.
	Planning errors.
	Communication failure.
	Multiple and complex sources.
	Lack of resources.
	Unsuitable processes.
Inventory	Information overload.
	Improper management settings.
	Complicated retrieval system. Work in progress (WIP).
	Planning errors.
	Poor layout.
	Lack of resources.
	Long setups.

Motion	Unnecessary movements due to poor layout of workplace.
	Poor housekeeping.
	Lack of resources.
	Information retrieval.
	Manual intervention needed.
	No direct access to resources or information.
	Incorrect placement.
Waiting	Shutdowns due to uneven flow (bottlenecks).
	Long set-ups.
	Insufficient staff.
	Communication issues.
	Insufficient information.
	Information is either too early or not available.
	Work is not in progress.
	Stopping and restarting activities.
	Lack of resources.
	Delays with the tasks.
	Planning errors.
	Waits on approvals, confirmations, licenses, etc.
	Availability of stakeholders

Overproduction	Over documentation.
	Excessive planning and controlling.
	Too much specification of requirements.
	Production forecasting for just in case.
	Extended set-ups.
	Incorrect requirement specifications.
	Non-harmonized and overlapped processes.
	Excessive signatures.
	Unnecessary details and information.
	Overlapping activities.
	Overspreading.
	Information being pushed instead of extracted.
Over process	Re-work that is avoidable.
	Adding value beyond what the customer is willing to pay for.
	Displacement of the scope.
	Unscheduled overtime.
	Excess of approvals.
	Resources overloaded.
	Excess of revisions.
	Production of intermediate deliverables.
	Not understanding the needs of the customer.
	Normative overload.
	Unnecessary iterations.

	Too many data conversions.
	Excessive checking.
Defects	Unproductive meetings.
	Defective quality control.
	Inadequate repairs.
	Poor documentation.
	Missing standards.
	Lack of processes.
	Defective design.
	Incorrect specifications.
	Misunderstanding customer needs.
	Communication issues.
	Lack, useless or unaware of information.
	Inefficient and unnecessary meetings.
	Ignoring standards.
Non-utilized or	Unproductive multitasking.
underutilized talent	Staff performing the work not considered as experts.
	Poor involvement in troubleshooting.
	Lack of communication.
	Insufficient training.
	Failure to work in teams.
	Improper management.
	Lack of skills and competencies.
	Deficient organization.

5.1.3 Lean tools, techniques and methodologies applied in Project Management

Currently, an increasing number of various tools and methodologies are being adopted to manage the projects as alternatives to "traditional" Project Management. These include the Lean approach, Six Sigma, Agile, Scrum, among others (Tödtling et al., 2017). Lean approach enable the project managers to have all the project options, deliverables, timelines and alternatives to make a calculated decision based on the progress of the project (Cruz-Villazón, 2018).

Several Lean tools and methods are commonly used in Project Management. The PMI outlines a number of lean practices which are commonly used when managing projects. Among the ones that they highlight as particularly popular and useful are: 5 Whys, A3 Problem Solving, Continuous Flow, Gemba Walks, Error Proofing, Kanban, Kaizen, KPIs. Plan Do Check Act (PDCA), Root Cause Analysis, Value Stream Mapping (VSM) and Visual Management (PMI, 2022).

The tools and methods that are more used in Project Management practices, according to the literature reviewed, are briefly described below. Some of them will be applied for the development of the Lean Project Management model for the identification of performance indicators within project-based organisations.

A3 Problem Solving

The A3 process is a structured, team-based collaborative problem-solving practice that extends the PDCA. A3 stands for the A3-sized paper template which is utilised to sketch out the planning along the problem-solving process. PMI features an A3 form with the following steps and sections (PMI, 2022):

Identify: Start by identifying the challenges and background information.

Summary: A detailed summary of the current state.

Objectives: State the objectives or desired future statement.

Analysis: Carry out a root cause analysis to understand the problems.

Solutions: Determine the necessary countermeasures to correct the situation.

Plan: Set out the plan to implement the countermeasures.

Results: Verify the outcomes to validate the solution.

Follow-up: Last, consider further actions necessary to maintain the results.

Five S (5S)

The 5S is a Lean tool consisting of five logical and sequential steps which are applicable for any setting, included Project Management. Project managers and project teams benefit from the use of 5S by saving time, budget, and effort, as well as increasing project efficiency and avoiding project delays or even failures (Tran, 2016). It is frequently misinterpreted to be a mere cleaning tool, but in fact it encompasses a

complete visual management technique (Bicheno & Holweg, 2016). In organizations and in projects it is used for continuous improvement through waste elimination and process optimization (Tran, 2016).

The five steps begin with the letter "S", hence the name "5S". In Japanese these steps are: Seiri, Seiton, Seiso, Seiketsu and Shitsuke meaning in English: Sort, Set in Order, Shine, Standardize and Sustain (Tran, 2016). Table 13 outlines the 5S steps, description and objectives of each step when it is applied in Project Management context.

Table 13: *Description of the 5S steps (Source: Jiwat, 2018; Tran, 2016)*

Steps	**Objective**	**Description**
Sort	To clean the workplace and eliminate clutter.	Identify and classify items into groups or types. Remove unnecessary objects and store infrequently used ones. This step in a wider context can be considered to sort from the 4M (Man, Machine, Method, and Material) perspective. These actions would increase efficiency and productivity.
Set in order	To put items in order.	Label and assign a place for each object in this step it is about placing, organizing, sequencing, and arranging the required elements in a user-friendly manner, enhancing the workplace's overall efficiency.

Shine	To clean in depth.	This step should be done on a very regular basis to detect defects more easily and more quickly. This avoids a decrease in productivity.
Standardize	To systemize the operation of the previous steps.	Set up standard processes for steps 1-3. This reduces confusion and uncertainty.
Sustain	To maintain the new standards and processes.	Evaluate 5S performance. Adapt and modify established standards to new circumstances.

The 5S is a continuous process aimed towards making the workplace more efficient and effective. Applied in a project context it helps to reduce risks in terms of delays, lead times, reduction of rework (Tran, 2016), as well as eliminating material waste and avoiding potential quality problems (Jiwat, 2018). This method can be a value-added activity in Project Management. For instance, in Product Development projects these steps can lead to re-engineering of the product design to eliminate over-engineering solutions and to avoid technical frills which are of no value to the customer (Jiwat, 2018)

Jiwat (2018) described the use of this technique, in Project Management, illustrating it with two types of projects: Construction project and Product Development project. According to the author, 5S can be employed individually at different project phases.

5S approach appears to be more meaningful to be used in a team environment (Jiwat, 2018). In other words, the teams of Planning, Design, Execution, Quality Control and Procurement can apply these 5 steps on a standalone basis. Nevertheless, if overlap exists between areas, the 5S can be enhanced within or between teams (Jiwat, 2018). Work and communication processes can be standardized.

Research was found in which Safety is included as a sixth S changing it to a 6S model. The addition of Safety is considered an appropriate and necessary extension (Jiwat, 2018). This new S is intended to ensure that the operating processes and work environment fulfil the safety standards (Jiwat, 2018).

Kanban and Visual Management

The visual management approach is a means of communicating relevant information visually in a form for which minimal or no prior training is needed to understand the content (PMI, 2022). Lean processes rely strongly on visual displays to strengthen standards, to identify irregularities, and to visualise performance. Everyone will be able to readily evaluate the situation, including the random viewer (PMI, 2022).

Kanban is a visual management tool widely used in Project Management in all types of projects. It is well recognised within the industrial sector as a tool for Lean Manufacturing. It became increasingly sought by the software development industry

(Lei et al., 2017). Moreover, it is also commonly used in Agile software product development as a mean to visualise the project displayed on cards presented on boards (Maneva et al., 2016).

The core focus of Kanban is to indicate precisely which work must be performed and when it should be done. This is done through prioritisation of work tasks and by defining the workflow along with the time for delivery(Lei et al., 2017) having a focus on "just-in-time" delivery (Maneva et al., 2016). It is employed to build a "pull" system in which the work of each process step is triggered by the next process step. This method is often practised to reduce and control stock or work-in-process (WIP) as well as any other kind of waste due to over-production (PMI, 2022).

In Japanese "kan" means "signal", and "ban" signifies "card" or "board" (Maneva et al., 2016). Therefore, Kanban is referring to "signal cards" that indicate the need for a certain product. The signal indicates that a task should be started following a "pull" system one of the principles of Lean. Kanban was created by Taiichi Ohno, while working at Toyota he visited a supermarket on his trip to the United States, and observed the shelf replenishment system using the pull mechanism (Maneva et al., 2016).

The principles followed by the Kanban methodology are outlined below (Lei et al., 2017):

- Limit Work in Progress (WIP).

- Pull value out of the development process.
- Make the process visible.
- Increase throughput.
- Use a fixed backlog.
- Integrate quality.

Lean and Agile

Lean and Agile complement each other. Their differences and similarities demonstrate that they do not have to be treated in isolation or progressively, since each contributes in its own way may also be combined with each other (Fan et al., 2007). Within the literature appeared several frameworks and models that interconnect the concepts of Lean and Agile together.

Agile was originally developed within the software industry, however a number of different sectors, among them the construction field, have incorporated the Agile system as well. Increasing the business value, relevance, flexibility, quality and business value are the main goals of Agile (Sohi et al., 2016).

Sohi et al. (2016) developed a blending of Lean Construction principles and agile project management approach to deal with the complexity of the projects. The authors researched the new management methodologies, including Lean and Agile

project management leading to the finding that these approaches may contribute in dealing with project complexity (Sohi et al., 2016).

It was noted by Putnik and Putnik (2012) that Lean is predecessor of agility (as cited in Mostafa et al., 2020) thereby Lean Thinking brings credibility and strength to the central concept of agility, while the link of these two approaches is grounded in their mutual support (Mostafa et al., 2020). Lean insights were helpful in providing a context and specific tools for Agile development.

Naylor et al. (1999) combined the Lean and Agile approaches resulting into a model coined "Leagile". For the development of this contribution was also brought in the Supply Chain Management (SCM) by leveraging the main features of the Leagile blend (Demir et al., 2012). Nevertheless, the authors claimed that this linkage was possible while considering the decoupling point model. This means that the shift from Lean to Agile or conversely, within SCM is possible as long as it is sequential.

Demir et al. (2012) studied the potential of management method based on combining Lean and Agile approaches. Such research takes place in a construction project context. They proposed a model that enables Project Management, Lean and Agile methodologies to be integrated into a single unit. The method proposed by these authors is called “AgiLean Project Management PM”.

Plan-Do-Check-Act (PDCA) cycle

Lean is based on the scientific method since it applies the Plan-Do-Check-Act (PDCA) cycle (Simon & Canacari, 2012). This is a problem solving and continuous improvement framework based on a four-step process. The model helps to create a structured and easy way to address issues and generate positive change (PMI, 2022).

Plan: Analyse and identify the change for improvement.

Do: Develop solutions and implement the change, usually on a small scale.

Check: Study the results by tracking the solutions and make improvements.

Act: Implement the change and repeat the cycle.

Root Cause Analysis

Root Cause Analysis (RCA) is a generic terminology that encompasses multiple tools (Ariyanti et al., 2021) to identify the root cause or multiple root causes of an issue (PMI, 2022). The 5-Why analysis is useful for classifying qualitative data according to distinct categories. Quantitative data is then obtained by using the FMEA framework tools (Ariyanti et al., 2021). Such tools typically embody (PMI, 2022):

- 5 Whys
- Ishikawa (Fishbone) Diagram
- Pareto Analysis
- Scatter Diagram

- Fault Tree Analysis
- Causal Loop Diagram
- FMEA

Value Stream Map

Each project is different and each one with many information flows occurring at the same time, this makes it very difficult to follow up. Value Stream Mapping is a useful instrument for understanding any process. It allows to identify the waste within the process and to develop a vision of a future stage. It is a model line, a map of the value stream with a person clearly responsible for visualizing the current state of the process. The data inside the VSM has to be right, timely and relevant. The irrelevant, wrong, out-of-date data is Muda (Bicheno & Holweg, 2016).

Ballard & Howell (2003) developed the Lean Project Delivery System (LPDS) model for projects in the construction industry. As they state this model originated from theoretical knowledge from other industries (Lean Production). The LPDS focuses on several aspects of project delivery, including improved stakeholder dialogue, decision deferral, process design, elimination of waste, flow and pull (Ballard & Howell 2003 as cited in Cruz-Villazón, 2018).

Lean Product and Process Development

Existing market challenges like mass customisation, increased competition, short-term product life cycles as well as the constant changing needs of customers require a new Project Management approach for the development of products (Tödtling et al., 2017). Lean Product Development refers to the application of Lean Thinking throughout the entire product lifecycle from the beginning of production to delivery to the customer (Al-Ashaab & Sobek, 2013).

Embracing the Lean approach over the complete product lifecycle can lead towards a substantial improvement in the organization's performance (Al-Ashaab & Sobek, 2013). This methodology is centred on the creation of value, a continuous improvement environment and processes fostering collaboration and innovation using Concurrent Engineering (Al-Ashaab & Sobek, 2013).

Lean Startup

In 2008, the Lean Startup Methodology was introduced by Eric Ries and was subsequently widely disseminated with his book entitled "The Lean Startup" (Tödtling et al., 2017; Yordanova, 2017). Ries defines LSM as "the application of lean thinking to the innovation process" (Yordanova, 2017). The book describes a business model that enables a business to develop products and innovations by involving customers as early as possible in a joint development (Yordanova, 2017).

This process relies on the Build Measure-Learn (BML) feedback loop and learning validation (Tödtling et al., 2017). Lean Startup blends various concepts with agile, iterative and quick development techniques by using tools and elements to create and implement a continual feedback cycle (Yordanova, 2017). Lean Startup's basic principles rely on the Lean approach, featuring a focus on customer and value, along with the continuing flow of innovation activity, constant improvement. Experimentation of the organization's business model is done in an iterative way, in short sprints focusing always on learning, using the experiments performed (Yordanova, 2017).

Lean Six Sigma

Lean Six Sigma is a business improvement approach that integrates Lean and Six Sigma management philosophies. It is a *"process and product improvement methodology, a toolset, a point of view, and a business manner"* (Dursun et al., 2019). In conjunction Lean and Six Sigma are complementary. Lean approach focuses on eliminating waste from the process and on the other hand Six Sigma features concentrate on controlling the process statistically and eliminating process variation (Albliwi et al., 2015).

Lean approach focuses on eliminating waste from the process and on the other hand Six Sigma features concentrate on controlling the process statistically and eliminating variation.
(Albliwi et al., 2015)

Lean Six Sigma aids in achieving organisational goals by integrating Lean and Six Sigma tools, techniques and principles (Marti, 2005). Lean Six Sigma enables to identify the organization's Project Management issues and the root causes, as well as allowing an early selection among those to be addressed first (Tenera & Pinto, 2014).

Tenera & Pinto (2014) developed a model based on Lean Six Sigma that allows dealing with actions systematically and implementing solutions to sustain in the long term a continuous improvement of the organization's project management processes. It is customer centric and results driven (Dursun et al., 2019). It increases customer satisfaction and quality by reducing process variation.

The methodology of DMAIC (Define, Measure, Analyse, Improve and Control) is followed in Lean Six Sigma in order to eliminate the root causes of problem (Dursun et al., 2019). In each DMAIC phase, the steps are carried out sequentially with specific tools and methods used to determine the outcomes of each stage, depending on the processes involved (Dursun et al., 2019). The DMAIC process is presented (Figure 12).

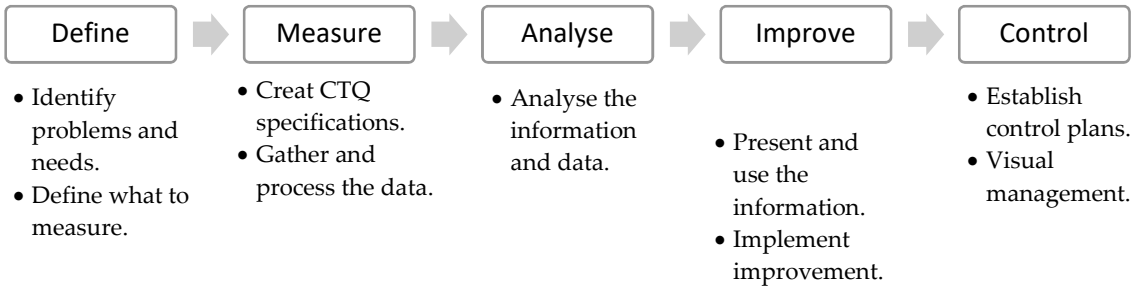

Figure 12: DMAIC methodology (Source: based on Donko, 2012)

Other tools and techniques that are used in Lean Six Sigma which are (Albliwi et al., 2015):

- QFD (Quality Function Deployment)
- FMEA (Failure Mode and Effect Analysis)
- SPC (Statistical Process Control)
- DOE (Design of Experiments)
- ANOVA (Analysis of Variance
- Kano Model

Research has been done on extending the DMAIC methodology to Project Management practices as well as process improvement. (Tenera & Pinto, 2014) in their publication, cite studies in which initiatives of Six Sigma include projects performed in order to achieve a single outcome, as in Project Management. These studies argue that a high potential lies in the integration of DMAIC and Project Management since the focus is to identify solutions to challenges and problems. However, despite the current mainstreaming initiatives suggested above, there are few existing efforts to integrate the Lan Six Sigma approach to project management process improvement intended to provide ongoing results (Tenera & Pinto, 2014).

5.2 Lean in Project-Based Organizations

Little research evidence is found about applying Lean to project-based organisations (Sundqvist et al., 2017). When Lean is linked to Project Management, the construction industry is primarily taken as an example (Ballard & Howell, 2003).

Even though Lean Project Management practices appear to be quite new, although not many authors described in detail about its underlying theory and its suitability for projects mainly in the construction and software development sector. However, it was detected a lack of research on its application to other types of projects such as RTD projects. Following is mentioned the findings of the SLR on project-based sectors involving the use of Lean.

5.2.1 Lean Construction

Lean construction refers to the application of the Lean approach to construction projects (Ballard & Howell, 2003). Lean Construction's main objective is to apply lean thinking, moving from the manufacturing perspective to construction activities, in order to improve the quality and efficiency of projects, thus reducing costs and minimizing waste (Silva et al., 2021). Over time, Lean Construction has continued evolving and has become an effective technique used in the construction industry for achieving a strategic approach (Silva et al., 2021).

Due to the increasing complexity of construction projects, this sector deals with a broad set of challenges. As a result, traditional construction practices are being shifted towards more advanced methods to achieve better results (Silva et al., 2021). In 1993 Lean Construction approach was introduced with success in the Architecture, Engineering and Construction (AEC) industry by Lauri Koskela (Demir et al., 2012). Koskela's approach was further extended by Ballard (2000), yielding as a result a new concept named Last System Planner (LSP) (Demir et al., 2012).

Subsequently, based on these theoretical insights, (Ballard & Howell, 2003) developed an even more specific model called the Lean Project Delivery System (LPDS) for construction projects. LPDS focuses on several aspects of project delivery, like improving stakeholder dialogue, decision deferral, process design, waste elimination, flow and pull (Ballard & Howell, 2003).

As an additional tool to support the construction industry, in 2003 the PMI published a supplement to the PMBOK Guide under the title "Construction Extension to the PMBOK Guide". For each new edition of the PMBOK Guide an update of this extension is being performed, in order to remove the processes and references that eventually become obsolete (PMI, 2016).

Sohi et al. (2016) developed a blending of Lean Construction principles and Agile project management approach to deal with the complexity of the projects. Underlying the causes of performance problems in construction projects, such as

delays and budget overruns, have been extensively researched since these issues are quite frequent (Sohi et al., 2016).

5.2.2 Lean Software Development

It is also possible to implement Lean in software projects, and in doing so, organizations learn through hypothesis-driven problem solving, streamlined communications, simplified processes, and to a lesser degree, specified tasks (Staats et al 2011 as cited in Cruz-Villazón et al., 2019).

Lean applied to Software Development it is known as Lean Software Development. Poppendieck and Poppendieck (2003) argued that software development itself is really a sub-set within the general process of product development (as cited in Alahyari et al., 2019). The authors assert as follows: *"It is the product, the activity, the process in which the software is embedded that is the real product under development"* (Poppendieck and Poppendieck 2003 as cited in Alahyari et al., 2019).

Further research has been conducted on the use of Lean Software Development projects. Sousa et al. (2018) using the action research methodology, investigated the application of Project Management best practices in conjunction with Lean methodologies in order to improve company's overall performance.

5.2.3 Lean in Research and Technological Development (RTD) projects

Research and technological development (RTD), as it is called in Europe, is also known as research and development (R&D). The application of Lean in sectors such as construction, software development, and product and process development is well consolidated. However, in the case of RTD projects, little evidence has been found regarding its link with Lean (Ali et al., 2014).

Despite the fact that Lean in RTD is a rather new approach (Ali et al., 2014), a research from 15 years ago was identified. Marti (2005) explored the use of Lean for performance improvement within the RTD projects (as cited in (Cruz-Villazón et al., 2020). The author describes in detail the way Lean Six Sigma allows a better understanding of the customers' critical requirements, adding value to services and enhancing the key areas of the RTD process (Marti, 2005 as cited in Cruz-Villazón et al. 2020).

Furthermore, more recent research demonstrates a positive effect of Lean implementation within this field. Applying the principles and tools of Lean in RTD organisations has the potential to strengthen their core competencies while improving their efficiency and decreasing waste and thus costs (Foruhi et al., 2018 as cited in Cruz-Villazón et al., 2020). The identification and determination of the value added

for the customer represents the central objective of Lean and is applicable to all disciplines, for instance, to the RTD industry (Foruhi et al., 2018 as cited in Cruz-Villazón et al., 2020).

5.3 Key Performance Indicators and Lean Project Management

The complexity of today's projects puts additional pressure on companies to understand the identification, selection, measurement, and communication of project metrics (Kerzner, 2017). Performance is a general characteristic across the industries for competitive advantage and it may be measured in terms of perceived customer value (Horman & Kenley, 1996). KPIs and performance metrics can be used to show managers and decision-makers a detailed picture of how the company's operations are performing, by displaying the degree to which the business objectives are being reached (Sousa et al., 2018)

Horman & Kenley (1996) provided a concise description of the key components of performance improvement. According to the authors, performance is defined as effectiveness and efficiency, the first referring to the maximization of value and the second to the minimization of non-value adding elements. As concluded in their work,

this means that performance is measured in terms of obtaining value effectively and efficiently.

Key Performance Indicators (KPIs) are metrics used by organization to track the success and guide their progress towards specific strategic objectives. In the context of a project, KPIs are related to the success or failure of the project. (Kerzner, 2017). Such indicators must be measurable and controllable, thereby quantitative and qualitative. (Kerzner, 2017; Toor & Ogunlana, 2010).

> ***"In a project context, KPIs are linked to the project success or failure"***
> *Kerzner(2017)*

KPIs should be adapted to all organisations since they are different and each has its unique needs and goals, however, the use of a generic framework may help to provide some guidance (Toor & Ogunlana, 2010). Kerzner (2015) argued that a KPI's crucial feature is that it is actionable, which basically refers to the fact that action could take place in order to rectify every negative trend (as cited in Cruz-Villazón et al. 2020).

In Cruz-Villazón et al. (2020) paper a collection of categories and indicators published in different research was made. This categorisation is outlined in Table 14. The categorisation provides an example for what can be included as a category in an organisation.

Table 14: *KPIs categories list (Source: Cruz-Villazón et al., 2020)*

KPIs categories	Indicators	Sources
Financial	Increases in sales	Yang et al. (2007)

	Decreases in material	Yang et al. (2007)
	Inventory	Yang et al. (2007)
	Transportation expenses	Yang et al. (2007)
Strategic	Cost	Cortes et al. (2016)
	Quality	Cortes et al. (2016)
	Flexibility	Cortes et al. (2016)
	Stock	Cortes et al. (2016)
	Inter-organizational cooperation	Toor & Ogunlana (2010)
	Organizational learning	Toor & Ogunlana (2010)
Tactic		Cortes et al. (2016)
Operational	Cycle time	Yang et al. (2007)
	Utilization rate	Yang et al. (2007)
	Lead time	Yang et al. (2007)
	Forecast accuracy	Yang et al. (2007)
	Time	Toor & Ogunlana (2010)
	Cost	Toor & Ogunlana (2010)
	Quality	Toor & Ogunlana (2010)
	Customer satisfaction	Toor & Ogunlana (2010)

	Overall satisfaction of stakeholders	Toor & Ogunlana (2010)
Project (operational)	Project team's ability to manage project risks	Toor & Ogunlana (2010)
	Ability to resolve project problems	Toor & Ogunlana (2010)
Tecnical	Efficiency of execution	Toor & Ogunlana (2010)
	Managerial and organizational implications	Toor & Ogunlana (2010)
	Personal growth	Toor & Ogunlana (2010)
	Manufacturer's ability	Toor & Ogunlana (2010)
	Business performance	Toor & Ogunlana (2010)
Life cycle	Maintenance capacity	Toor & Ogunlana (2010)
	Energy consumption	Toor & Ogunlana (2010)
	User satisfaction	Toor & Ogunlana (2010)
Safety		Toor & Ogunlana (2010)

Sustainability (socio-economic aspect)	Social and human development in the area	Toor & Ogunlana (2010)

It can be helpful to use Lean tools like the five whys and cause-and-effect analysis to determine performance indicators (Cruz-Villazón et al., 2020).

Certain criteria are specific to a performance indicator measurement system within the context of product development (Dombrowski et al. 2013). Such criteria include the importance for the company's objectives, the quality of the data (validity and timing), the compatibility with the hierarchy, the variability (reacting rapidly to changes), the periodicity, the visualisation and the effort (Cruz-Villazón et al., 2020).

On the other hand, Kerzner (2015) identifies six main features for KPIs that are project-oriented: predictive (future), measurable (quantitative), actionable (changes to be corrected), relevant (relation to project success/failure), automated (reports minimise human error) and few in number (those necessary) (Cruz-Villazón et al., 2020). Table 15 below presents a list of the characteristics required for KPIs.

Table 15: *KPI characteristics from SLR (Source: Cruz-Villazón et al., 2020)*

	Dombrowski et al. (Dombrowski et al., 2013b)	Iuga et al. (Iuga et al., 2015a)	Kerzner (Kerzner, H., 2017)	Toor & Ogunlana (Ogunlana, 2010)
Actionable			**x**	
Automated			**x**	
Compatibility (hierarchy)	**x**		**x**	
Effort	**x**			
Few in number		**x**		
Helpful		**x**		
Measurable			**x**	**x**
Objective				**x**
Periodicity	**x**			
Predictive			**x**	
Relevant	**x**	**x**	**x**	
Timeliness	**x**			
Valid	**x**	**x**		
Variability (react quickly to changes)	**x**			
Visualization	x			

Focusing on customer value and waste reduction in Lean drives the to the assessment of the performance indicators inside the organisation (Cruz-Villazón et al.,

2020). The main KPIs are set in such a form that they have an effect on the organisation's most significant results (Cruz-Villazón et al., 2020). While core indicators may differ between organisations, a process built using Lean can help to define a business's KPIs (Cruz-Villazón et al., 2020).

A literature review was carried out for Lean and KPIs topics. The results obtained from this review are displayed in the Table 16. The information on each publication concerning its content related to any Lean tool, principle, is listed in the table. Also their respective output or contribution, and KPI coverage was analysed.

Table 16: *Lean and KPIs content found in the publications (Source: Author)*

Reference	**Lean use (org. level)**	**Lean approach**	**Lean tools**	**Lean principles**	**Performance indicators**	**Output / Purpose of the study**	**Sector / Field**	**Discipline**
Chakrabarty & Chuan (2009)	Strategic, operational	Six Sigma	DMAIC, CTQ	N/S	KPI, critical succes factors (CSF)	Conceptual framework	Service	N/S
Cortes et al. (2016)	Strategic	Lean Management, Lean Six Sigma	VSM	Waste	KPI	Framework	Manufacturing	N/S
Dombrowski et al. (2013)	N/S	Lean product development	N/S	Waste	KPI	Rules for creating performance indicators	Manufacturing	Product development
España et al. (2012)	N/S	Lean	Lean Project Delivery (LPD)	N/S	KPI	N/S	Construction	PM

Iuga et al. (2015)	Shop floor level	Lean	N/S	Waste	KPI	Model	Manufacturing	Shop floor
Marti (2005)	N/S	Lean Six Sigma	N/S	N/S	KPI	N/S	Pharmaceutical	R&D
Oguz et al. (2012)	N/S	Lean Six Sigma	CTQ, VSM	N/S	Performance indicators	N/S	Construction	PM
Panagopoulos et al. (2017)	N/S	Lean Six Sigma	DMAIC, CTQ	N/S	KPI	Model and conceptual framework	Aviation	Safety
Roberts & Latorre (2009)	N/S	N/S	System Dynamics theory	N/S	KPI	N/S	Construction	PM
Toor & Ogunlana (2010)	N/S	N/S	N/S	N/S	KPI	Analysis of variance (ANOVA), t-Test	Construction	PM

Yang et al. (2007)	Strategic, operational	Six Sigma	DMAIC, CTQ, QFD	N/S	KPI	N/S	Manufacturing	PM, SCM projects

* N/S not specified

Chapter 6 Proposed Lean Project Management Model

The previous chapters have analysed the feasibility of applying a Lean Project Management approach and discussed the importance of identifying KPIs to measure project success. As a result, a Lean Project Management model is proposed to be employed for the identification of these KPIs. The theoretical concepts reviewed previously provided the basis for designing this model. Additionally, throughout the development of this model, issues concerning success factors and Lean methods linked to performance measurement identified in other studies, were integrated.

A model was developed to enable the integration of Lean thinking and practices into Project Management (Figure 13). Solid, practical techniques and models are needed to support project teams in dealing with waste issues within projects (Ansah et al., 2016). This model is built on the theory found in the conducted SLR, and intent to integrate Project Management practices in connection with the Lean principles and practices.

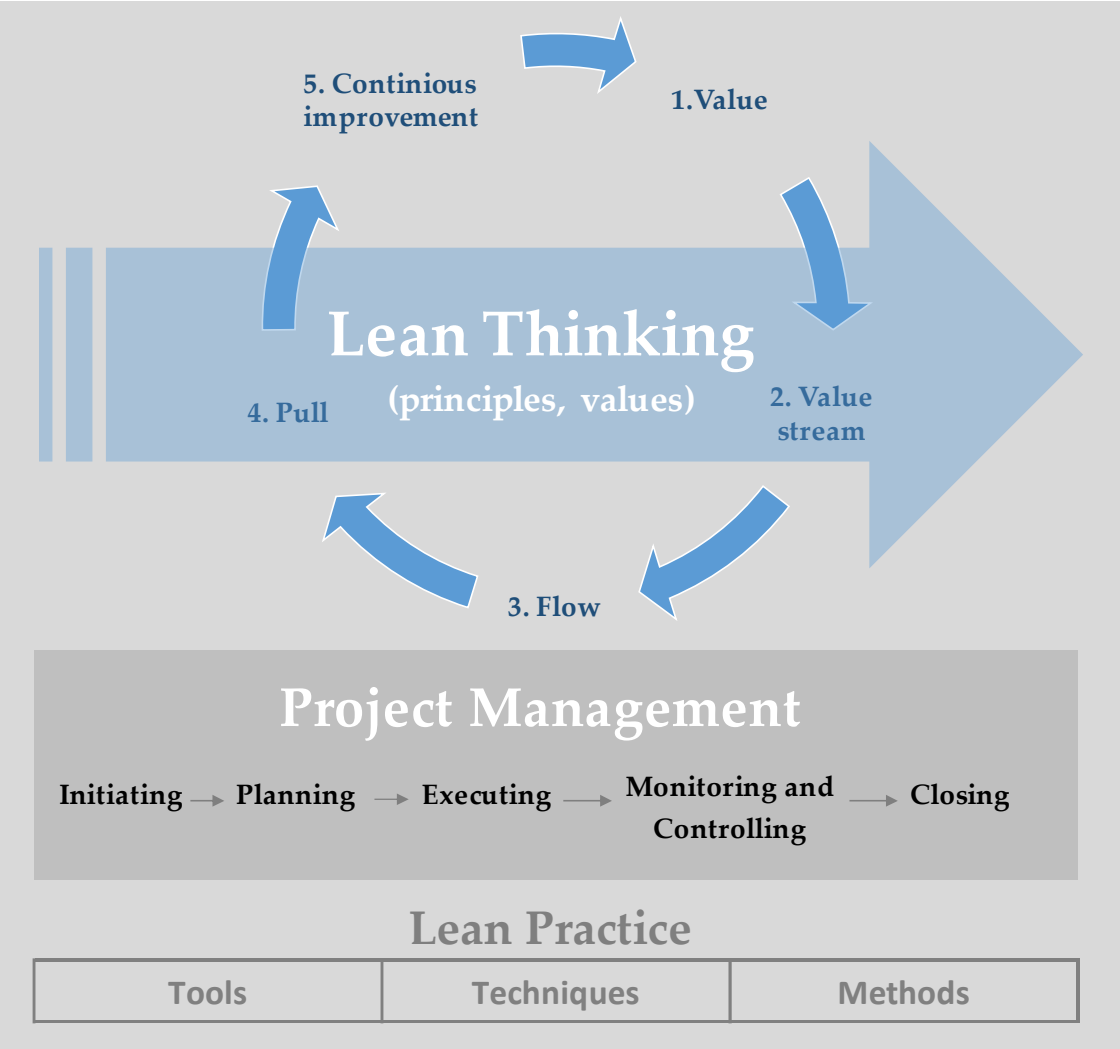

Figure 13: Lean Project Management model (Source: Author)

The Lean Project Management model embodies the Lean approach consisting mainly in a set of principles. These fundamentals first define the value from the customer's perspective, then continue to trace the value stream process for achieving value, followed by the creation of the value flow, ending with the creation of a pull system for striving towards perfection.

Lean encompasses a range of diverse tools, techniques and methods to be tailored according to the nature of the project. It is important to realize the need for selecting the most suitable selection of Lean tools, techniques and methods in order better manage wastes and make decisions.

Likewise, this model has a dual component. Firstly, it addresses the Lean approach as a way of coordinating all the processes involved in generating project value, including the project lifecycle from initiation, planning, execution, control and finally project closure. As projects can be treated as "temporary production systems" they can be designed, planned, produced and delivered in a given time frame (Ansah et al., 2016). The Project Management section inside the model represents, in addition to the project life cycle, the guidelines, standards, process and concepts related to the management of projects.

Consequently, it is possible to achieve an optimum benefit over the process, since value is obtained both in terms of efficiency and the flow and value creation. It represents a value perspective to the stakeholders concerned in a continuously improving approach. Since it is based on this fundamental premise, the Lean Project Management principles outline the mind set required for successful project delivery.

6.1 Lean Project Management Model for the identification of KPIs

For the identification of KPIs in a project context the proposed Lean Project Management model was applied and tailored. The Lean Six Sigma DMAIC (Define, Measure, Analyse, Improve and Control) central concepts (Figure 14) were used for the elaboration of the model. This methodology provides a structure to the analysis based on a cycle-based approach (Papadopoulou & Özbayrak, 2005). It also allowed the Lean KPI model to remain focused on customer value one of Lean's principles.

The DMAIC method is adopted for detecting and eliminating the root causes of the problem. In each phase, the steps are carried out sequentially with specific tools and methods used to determine the outcomes of each stage, depending on the processes involved (Tenera & Pinto, 2014). These five process phases will be described below (Figure 14).

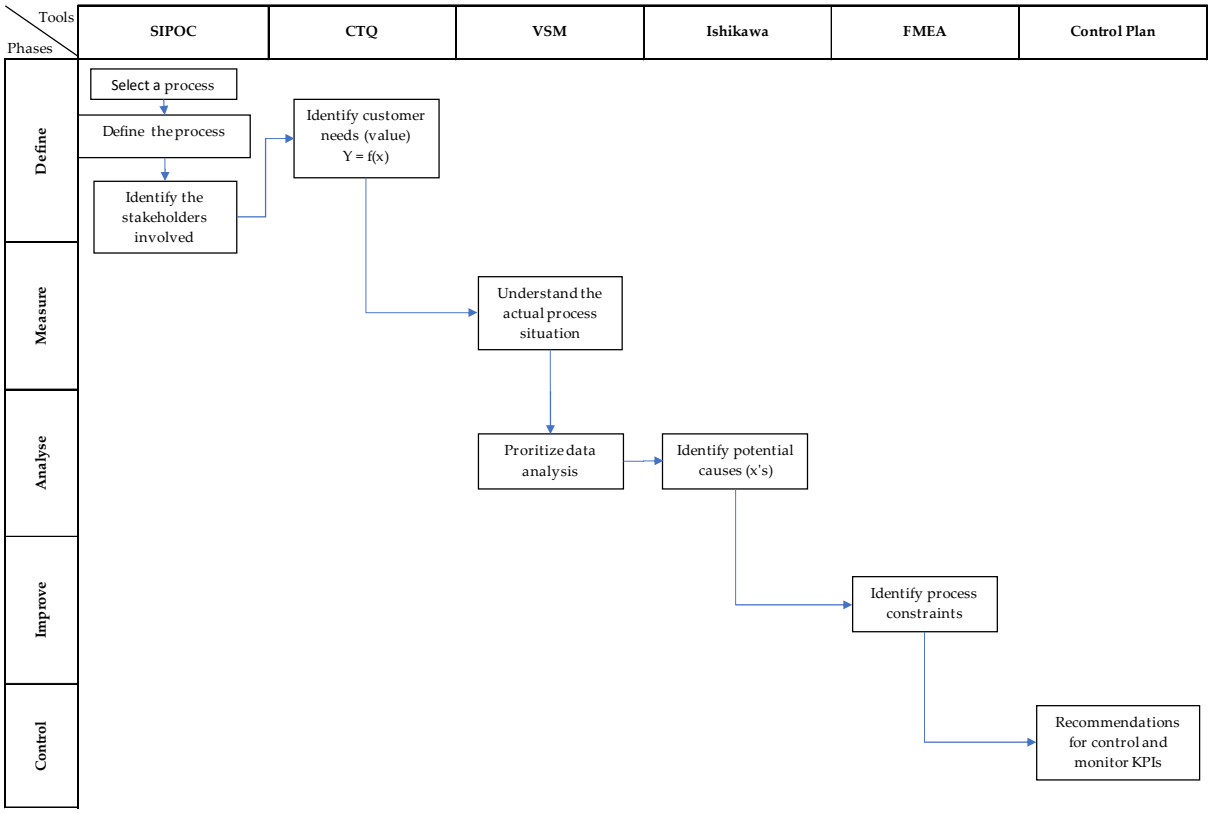

Figure 14: Identification of KPIs following DMAIC process steps (Source: Author)

Define phase

The first step of the Define phase is to verify that the project scope is consistent and in line with the strategy of the company. Such an activity will allow detecting whether or not the performance aspects fulfil the expectations of the customer (Marti, 2005 as cited in (Cruz-Villazón et al., 2020). The most frequently used Lean tool to capture customers' needs and demands is the so called Voice of the Customer (VoC) (Gaskin et al., 2010). Afterwards, the collected data from the VoC may be utilized for the identification of performance indicators (Cruz-Villazón et al., 2020).

By means of VoC it is possible to identify the customer's critical requirements and use a process to collect and organize these data (Gaskin et al., 2010). It consists of a four-step process that entails the following actions (Gaskin et al., 2010):

1) Capturing the customer's needs.

2) Organizing the information in a hierarchical structure.

3) Prioritizing in terms importance

4) Gathering customer perceptions of importance.

A similar process is also available called Voice of the Business (VoB). This process follows the main concepts and process of VoC, with the difference that the VoB process focuses on the organization's objectives (Papadopoulou & Özbayrak, 2005).

Measure and Analyse phase

For the Measure phase, the specifications gathered in the VoC and in the VoB are transferred in factor that can be measured and monitored by means of the Critical to Quality (CTQ) tool (Cruz-Villazón et al., 2020). This information processing is referred to the process of converting the data into quantitative data and are linked to the organization's objectives (Cruz-Villazón et al., 2020). This tool indicates the expectations of the customer with respect to the quality of a product. They are

commonly displayed as a descending tree diagram and are referred as CTQs when they are applied to performance indicators (Cruz-Villazón et al., 2020).

Figure 15 (based on Kerzner, 2015) shows the generic representation methodology of a project. It involves an input such as requirements and statements that are given by the stakeholder, and a process for delivering an output.

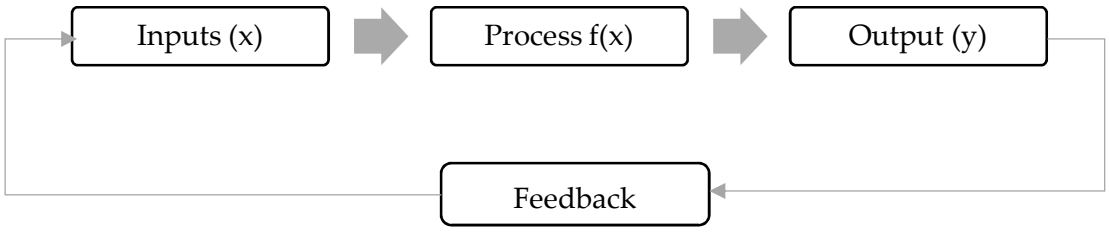

Figure 15: Process flow (Source: Author)

A similar process flow called SIPOC (supplier, input, process, output and customer) is used in Lean Six Sigma (Figure 16). It provides guidance for identifying metrics and KPIs (Cruz-Villazón et al., 2020).

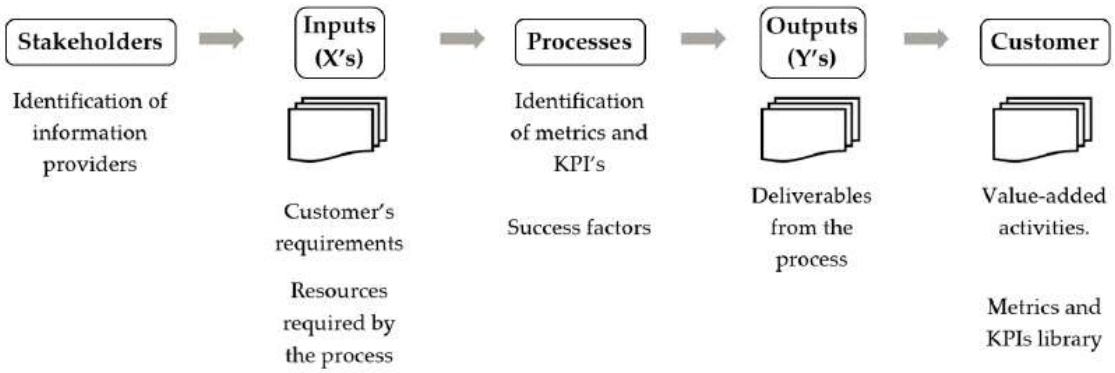

Figure 16: Supplier, input, process, output, customer (SIPOC)—process representation (Source: based on Kerzner, 2015; Orguz et al 2012).

In CTQ, outputs are denoted as Y and inputs are designated as X, which are the factors influencing the outputs (Orguz et al 2012 (Cruz-Villazón et al., 2020). The CTQ specifiers are the dependent variable Y measures and the X's are the lead variables which are the drivers (Cruz-Villazón et al., 2020). Factors influencing CTQ are illustrated in the following equation.

$$Y = f(X)$$

CTQ's current state is determined and the key variables X's or performance measures will be sought (Cruz-Villazón et al., 2020). The Value Stream Map (VSM) can be used to identified the X's and also facilitates the recognition of value-added and non-value-added activities in a downstream processing chain (Cruz-Villazón et al., 2020). VSM uncovers problems hidden in the process as well as highlights

opportunities and allows to optimize performance through the reduction of waste (Cruz-Villazón et al., 2020).

Following the definition and the comprehension of this complete process, as well as specifying and documenting all detected performance measures, it is possible to move on to the next phase of the DMAIC, which is the Analysis phase. During this step, it is possible to pinpoint the critical factors which are connected directly with the Ys (Cruz-Villazón et al., 2020). An accurate and consistent analysis of the information and the activities of the process enables to identify those major drivers affecting the quality from the point of view of the customer, in other words, the added value (Cruz-Villazón et al., 2020).

The relevance of the CTQs lies in the fact that once they have been identified, the necessary information is obtained to establish the performance indicators. A measurement is then linked to that indicator and, subsequently, the organization's objective is established. Table 17 provides a proposed framework for defining and determining the KPIs for projects.

Table 17: *Lean-based model for identifying KPIs (Source: Cruz-Villazón et al 2020)*

Categories	**VoC**	**Drivers**	**CTQ**	**Measurements**	**Target**
Proposed KPIs categories detected in the SLR	Customer's need Organisation's strategies	Parameters to be measured	The performance indicators	Data at a single point in time, specific, measurable	Organisation 's goal
	What do the customer most expect?	**How** does this need can be satisfied?	**How** to measure each quality driver?	A data point at a single point in time, specific, measurable	**What** do the customer most expect?

Improve and Control phases

The objective of this fourth phase of the DMAIC is to identify potential actions for improvement. In this step it is possible to measure the "on time" achievement of the customer agreed milestones (Marti, 2005). Furthermore, the forecasted resources for task execution can be checked in comparison to the real resources employed (Marti, 2005). The assessment of KPIs delivers insight regarding performance and the capacity for achieving the expectations of clients (Marti, 2005).

After identification and categorization of the KPIs, the next step is validation, adaptation and monitoring of these indicators (Cruz-Villazón et al., 2020).For controlling progress, using monitoring "dashboards" are recommended (Marti, 2005). Also a web application, such as the customized scorecard, is suggested for getting the required project management standards and tools (Cortes et al. 2013 (Cruz-Villazón et al., 2020).

Chapter 7 Case Study

In this chapter, it will be described the RTD project-based organization in which the case study (CFAA) was conducted. Subsequently, the current situation of the CFAA is discussed as well as the type of projects being carried out in this organization. Further on, it outlines the dimensions of success for this company along with the criteria defined for project success. Finally, the KPIs are analysed and benchmarked with the German cluster ruhrvalley for the identification of these indicators. The development of this case study was published in (Cruz-Villazón et al., 2020).

The case study research strategy helps to gain a deeper understanding of a topic and it is useful to bring it within a realistic context. This entails an empirical research on a specific current event in its real-life setting utilizing a variety of available sources of evidence (Saunders et al., 2016). In particular, qualitative case study methodology allows researchers to conduct a detailed investigation of complex issues embedded in a specific situation (Rashid et al., 2019).

This approach can be tackled according to the epistemological perspective of the researcher (Saunders et al., 2016). It consists in following a comprehensive and

detailed research, generally based on empirical evidence collected during a specific period of time. The aim of a case study is to conduct focused research about a particular case, like an individual, or a group, an institute or even a community allowing the identification of key factors, processes and relationships (Rashid et al., 2019).

The case study undertaken in this thesis was based on the four phases of the systematic guideline for conducting case studies together within a supportive literature review proposed by (Rashid et al., 2019). The case study was carried out within a project-based company that mainly works with RTD projects. It consisted in the application of the Lean-based KPI model developed during the thesis for the identification of KPIs.

7.1 Company description: CFAA (Advanced Manufacturing Centre for Aeronautics)

During the last decades, the machine tool manufacturing and advanced aeronautics sectors have been one of the strategic sectors for the economy of the Basque Country in Spain (Cruz-Villazón et al., 2020). The Advanced Manufacturing Centre for Aeronautics (CFAA) was created in response of deciding to create a

Research, Development and Innovation Centre (R+D+I) focused on advanced aeronautical manufacturing technologies (Cruz-Villazón et al., 2020). It integrates these sectors with the University of the Basque Country (EHU/UPV) enabling an easy and quick transfer to the industrial productive ecosystem associated to the value chain (Cruz-Villazón et al., 2020).

The CFAA is an open and common space for researchers, students, industry professionals, companies and research centres operating both nationally and internationally, providing applied knowledge, technologies and new methodologies for the aforementioned sectors (Cruz-Villazón et al., 2020). Additionally, this project is supported by the Provincial Council of Bizkaia and by the Society for Competitive Transformation (SPRI) in its origin, establishment and in the acquisition of facilities and machinery (Cruz-Villazón et al., 2020).

7.1.1 Current Situation

CFAA screens those projects aligned with its strategy by seeking to demonstrate their economic, scientific and technical feasibility in an industrial environment designed and equipped to reproduce a real plant (Cruz-Villazón et al., 2020). Through the interaction of multiple scientific groups, CFAA offers, develops and tests advanced manufacturing technologies, techniques and applied knowledge, resulting from state-of-the-art research (Cruz-Villazón et al., 2020).

The CFAA is a project-based organization. In this centre, the success of the projects plays an important role in the present and future opportunities (Cruz-Villazón et al., 2020). These include opportunities to participate in European calls, to join international and specialized clusters, or to recruit young and professional candidates (Cruz-Villazón et al., 2020).

However, some studies carried on CFAA had demonstrated that there are still major improvement opportunities to measure and improve the rate of success in this Centre. Nevertheless, it has been noted at this point that considerable improvement areas remain to be addressed in order to measure and improve this CFAA's success rate. (Cruz-Villazón et al., 2020).

The CFAA has been committed to promoting scientific activity and contributing to several scientific publications, such as journals with different impact indexes, conferences, book chapters, etc. (Cruz-Villazón et al., 2020). At present, the CFAA is working on the implementation of a project management methodology developed specifically for the centre, which aims to manage projects, programs and portfolios, and drive the organization towards greater agility and efficiency (Cruz-Villazón et al., 2020).

Although the CFAA is in quite good condition in terms of its scientific production, use of resources, collaboration with institutions and participation in European cooperation projects, several of the general goals set for the company and

those described in the Center's Quality Manual are still poorly studied, outlined and measured (Cruz-Villazón et al., 2020).

7.1.2 CFAA Success Dimensions

For CFAA and its main stakeholders, project success depends on the area (or dimension) being inspected, so these areas need to be approached individually, covering both the business side and people management (Burimova et al., 2020 as cited in Cruz-Villazón et al., 2020). Therefore, defining and assessing the success criteria in the different dimensions is crucial (Cruz-Villazón et al., 2020). For the purpose of this study, the success dimensions selected are presented in the following table (Table 18).

Table 18: *CFAA success criteria (Source: Burimova et al., 2020 as cited in Cruz-Villazón et al., 2020)*

Success criteria	*Description*
Project Management Success Dimensions (PMSD)	A focus on the required aspects for proper project management, such as time, cost, scope, quality compliance, resource and stakeholder management, and so forth.
Delivery Activities Success Dimensions (DASD)	To concentrate on processes that are employed to produce the deliverables.
Deliverable Success Dimensions (DSD)	Description of the project output, including the success criteria necessary to ensure that the final project output meets the scope.

Operations Success Dimensions (OSD)	Including the success criteria required to verify that the operation guarantees the ongoing project process to be carried out in an acceptable manner.

7.1.3 CFAA Key Performance Parameters

It is necessary to analyse the performance parameters adopted by similar centres in order to compare and understand their rationalization of their measurement parameters from a mature perspective (Cruz-Villazón et al., 2020). In this research, ruhrvalley was selected from several innovation centres because of the following aspects (Cruz-Villazón et al., 2020).

One reason is due to its region (Cruz-Villazón et al., 2020). The companies that are part of the ruhrvalley innovation cluster are SMEs focusing on small yet highly advanced market niches and even some of them are positioned as global market leaders within their respective fields (Cruz-Villazón et al., 2020).

Another reason is because it is a cluster. ruhrvalley was established to offer broader solutions in areas such as eMobility, renewable energy systems and digital transformation (Cruz-Villazón et al., 2020). Its impact has been in solutions for urban mobility and energy systems, the innovation community in the region, the development of a strong innovation profile for universities and the development of

technology-driven start-ups and SMEs in the region (Cruz-Villazón et al., 2020). And finally its collaborative model which focuses on effective interaction among top universities and research centres, scientific and industrial associations, and relevant societal and political actors (Cruz-Villazón et al., 2020).

ruhrvalley as well as CFAA are pursuing a mix of applied research, academic education with a strong application focus (high TRL), cooperation with industry and a strong focus on innovation and entrepreneurship. In addition, both centres converge on the strategy "to increase the impact of R&D results in the scientific community" (Cruz-Villazón et al., 2020). Furthermore, both are focusing on the technologies of Industry 4.0 (Cruz-Villazón et al., 2020).

Chapter 8 Results and Discussion

The results of the SLR on Lean Project Management will be presented in this chapter. The information provided in the sections related to Lean Thinking and Project Management (Chapter 3 and 4) were mainly used as a background to contextualize and offer supporting evidence to demonstrate the feasibility of applying Lean in Project Management. Relevant findings resulting from the Descriptive Analysis of the SLR are described below. The application of the developed Lean Project Management model applied to the case study are also presented. It is explained the significance of the results obtained and the hypotheses proposed are answered.

8.1 Results and Findings from the SLR and Descriptive Analysis

A significant increase in the number of scientific papers published from 2003 onwards clearly reflects that Lean Project Management has gained interest and

increased popularity within the research community. It is possible to infer that Lean applied to Project Management is an emerging and trending research area.

Research linking Project Management and Lean proposed by Ballard and Howell (2003) and the development of their LSP model transformed the way in which projects were conducted, particularly in the Construction sector. Their paper *"Lean Project Management"* is the most widely cited publication in databases about this topic. Consequently, this explains the concentration of the largest amount of research on Lean Project Management focused mainly on the Construction sector.

The results reveal at a glance that researchers from China and USA are the leading contributors to Lean Project Management research. In the USA, Lean has become an essential component of the industrial environment over the past four decades and is widely accepted among academics and practitioners as being correlated with increased performance as well as its potential to provide a competitive advantage (Shah & Ward, 2007).

SLR has yielded a series of findings on the applicability of Lean in the management of projects. All information obtained through this process was analysed, highlighting the significant and outstanding findings described in the following section. Throughout the work done in this thesis, evidence was obtained to provide answers. Based on these observations and findings, the hypotheses previously stated in this study are now being addressed and can be answered.

8.2 Answering Hypotheses

H1: The combination of Lean Thinking principles and tools and Project Management practices can be applied in conjunction.

This research yielded an extensive array of data and findings concerning the Lean approach and Project Management practices. Lean is an ambiguous term and is defined by researchers using multiple interpretations. Lean has been discussed, both conceptually and empirically, from different perspectives in terms of methodology and philosophy. The literature revealed two tendencies regarding the purpose of Lean. One has a more internal focus towards cost reduction through the elimination of waste. Secondly, an external perspective, centred on the generation of value for the customer.

Lean is constantly evolving. Therefore, it becomes understandable that the performance in terms of availability is under constant challenge. With the development of research, these concepts are continuously being revised and updated to meet new market needs. Through Lean it is possible to eliminate the wasteful elements of a project (in any form) without affecting the final outcome.

A consistent fact is that Lean approach always starts with the customer followed with Lean practices. These are the activities that either directly or indirectly generate value from the customer's perspective including insights from flow

improvement, providing transparency across all work and workflow, and maintaining the workloads inside the scope (PMI, 2022). Through continuous experimentation it is intended to learn through innovation (PMI, 2022) at work in order to improve quality and workflow, delivering projects with minimum duration and consuming less resources, while reducing the waste.

Difficulty in defining and measuring the true value of the investment in Project Management has been increasing and value relies on its appropriate implementation. The adaptation of practices and the maturity of Project Management processes will have a significant impact on performance (Cruz-Villazón et al. 2020).

The PMBOK mentions that a number of Lean tools are used, such as the cause and effect diagram (fishbone diagram or Ishikawa diagram), the control chart, run charts, and the scatter diagram and FMEA. These Lean practices are suggested within the Project Quality Management knowledge area. This guide states that "quality improvement initiatives such as Total Quality Management (TQM), Six Sigma, and Lean Six Sigma could improve the quality of the projects" (PMBOK, 2017).

The term Lean Project Management has been developed and has been explored as a theoretical concept, but also it has been applied empirically. There is evidence of case studies of companies adopting this methodology successfully in their organisations.

In the literature analysed, the application of Lean principles, tools and techniques was mainly found for construction, healthcare, and software engineering projects (Mostafa et al., 2020). Lean applied to construction has led to the development of the term Lean Construction. Lean Construction has two principal contributions the first from Koskela, the Transformation-Flow-Value theory and the other from Ballard, the Last Planner System (LPS) technique.

Lean Project Management embraces Lean Thinking mind-set to execute a project in a more efficient way in order by delivering customer value. As any other methodology Lean should be tailored according to the type of project and the sector where it is being implemented. A construction project which has a statistic environment, a high degree of complexity and a big rage of stakeholders, etc. These are different characteristics compared to an IT project that has high variability and flexible (Demir et al., 2012). Furthermore, Lean tools not all have to be used together, it is necessary to select the most convenient ones considering the type of project.

H2: Lean Project Management has a positive impact for projects performance.

The SLR revealed a growing body of research aimed to explore the positive impact of Lean on project management. Old approaches to Project Management are not sufficient to deal with the current and future way of management of projects (Kerzner, 2017).

As the discussion illustrated, the underlying dynamics of the Lean approach can be applied to project-based organizations. Studies were carried out to develop a blend of Lean principles in construction projects alongside agile project management approaches to cope with the increasing complexity of projects. This new management methodologies, including Lean and Agile project management may contribute in dealing with project complexity (Sohi et al., 2016).

In the literature the following gaps were detected in today's Project Management, where Lean approach and tools can support and be complementary: a lack of understanding the necessary metrics to track progress of the project (Kerzner, 2017); and the lack of assessment tools to determine the project's value (Kerzner, 2017).

It is crucial to understand the correlation between the Lean approach and its tools in managing projects according to diverse key factors such as the sector, goals, complexity, environment, among others. Based on the above mentioned criteria, project managers are able to better identify which tool will deliver the optimal outcomes for the customer needs.

H3: In project-based organisations Lean Project Management covers the required aspects to manage their key performance indicators.

The complexity of today's projects puts additional pressure on companies seeking to understand the identification, selection, measurement, and communication

of project metrics (Kerzner, 2017). The metrics and KPIs need to be set up for critical tasks which can directly impact on project success or failure, therefore assumptions and value tracking is essential (Kerzner, 2017).

The results in Chapter 7 Case Study, show that important success factors, for the researched project-based organisation, were related to the safety at workplace, also if the project goal was achieved and how the customer feels about the quality of the different deliverables. These results are quite valuable as an input of the strategic needs that CFAA must necessarily focus on (Cruz-Villazón et al., 2020).

The adoption of KPIs to achieve objectives within the production environment is widely spread (Dombrowski et al., 2013a), although there is scarce research published on developing a model to identify the KPIs in project-based companies detected. The mentioned concepts have been studied in the past but a lack of homogeneous process for identification and measure of KPIs was detected (Cruz-Villazón et al., 2020).

8.3 Results from applying Lean Project Management Model to the case study

For the identification of KPIs in a project context the proposed Lean Project Management model was applied. The Lean Six Sigma DMAIC central concept was specifically used for the KPIs identification. First, it was verified that the scope of the project was aligned with the CFAA strategy. Customer needs and requirements were defined by means of the Lean tool. The information gathered throughout the VoC was applied for identifying the performance indicators

The main key performance indicators were set in order to have an impact on the organization's most relevant results (Cruz-Villazón et al., 2020). It was selected the categories from SLR, so the needs identified (VoC) and the organisational strategies and objectives (VoB) could be established in an organised way (Cruz-Villazón et al. 2020). SIPOC was then employed to identify metrics and KPIs. Data analysis and the process activities enable to determine the principal drivers affecting quality in terms of value added from the customer's perspective (Cruz-Villazón et al. 2020).

After completing those preliminary steps, it was proceeded to the identification of the parameters to be measured as the driving factors in order to achieve the future KPI. The identification of the CTQs gave the information required to raise the performance indicators. Following this, it could be proposed a tie in a measurement to that indicator like the number, the percentage or the, amount (Cruz-Villazón et al. 2020).

The organizational needs and strategies analysis included a search for CFAA documents containing useful information to guide the identification of performance indicators, such as data from a project success survey for stakeholders and staff of the organization, and benchmarking with a centre similar to the CFAA. Subsequently, stakeholder validation was conducted to ascertain their perception of the performance indicators (Cruz-Villazón et al., 2020). Finally, as a result of this process, the objectives of the organization could be determined.

Once the study was conducted, the resume of the results of the most important success factors are outlined in Table 19.

Table 19: *Most important success factors for CFAA and stakeholders (Source: Cruz-Villazón et al., 2020).*

No.	Success Factors	Success Dimension	References
1	Workplace Safety	OSD	(Project Management Institute, 2016)
2	Project goal was achieved	PMSD	(Pinto & Slevin, 1987, 1988)
3	Customer satisfaction regarding the quality of delivery activities of the specific project	PMSD	(McLeod et al., 2012)
4	Reputation of the organisation has increased	PMSD	(Khang & Moe, 2008)
5	Knowledge generation regarding project activities (e.g. tools, techniques, approaches, processes)	DASD	(Dvir et al., 2006)

6	Customer satisfaction regarding the management of the specific project.	PMSD	(Müller & Jugdev, 2012)
7	Customer satisfaction regarding the deliverable.	DSD	(Martens & Carvalho, 2016)
8	Degree to which the deliverable meets its intended purpose.	DSD	(Agutter, 2019)
9	Return on Investment of the project	PMSD	(Project Management Institute, 2016)
10	Workplace security	OSD	(Project Management Institute, 2016)
11	Completed within defined and agreed scope	PMSD	(Müller & Turner, 2007; Project Management Institute, 2018)
12	Completed within defined and agreed time	PMSD	(Müller & Turner, 2007; Project Management Institute, 2018)
13	Completed within defined and agreed costs	PMSD	(Müller & Turner, 2007; Project Management Institute, 2018)

Findings indicate the main success factors, which are primarily linked to safety in the workplace, as well as the achievement of the project's objective and the customer's perception regarding the quality of the outcomes (Cruz-Villazón et al.,

2020). Such results represent a valuable input to the strategic requirements on which the CFAA should focus (Cruz-Villazón et al., 2020).

A number of in-house CFAA documents served as the basis for analysing the organization's strategies and needs. These include meaningful information that drove the process of determining the performance indicator (Cruz-Villazón et al., 2020).s. This information included data collected from a survey carried out with stakeholders and staff to evaluate the success of projects, and a benchmarking assessment using a similar facility to the CFAA (Cruz-Villazón et al., 2020). A validation of the stakeholders was then undertaken to ascertain their perceived understanding of the performance indicators (Cruz-Villazón et al., 2020).

For the construction of the CFAA's KPIs, these were ranked in accordance with the study conducted by Wolff & Nuseibah (2017) (as cited in Cruz-Villazón et al., 2020). For this classification, a division of four different domains was made: Innovation, region, research and development, and university. Afterwards, a deduction was made concerning the strategic needs of each of these areas. As a result, a comprehensive strategic needs list for the CFAA was drawn up (Table 20) (Cruz-Villazón et al., 2020).

Table 20: *Strategic needs—CFAA (Source: Cruz-Villazón et al., 2020).*

Scope	Strategic needs
Innovation	• Create and marketing new services, product lines and technological capabilities. • Institutional support of SMEs with innovation impulses in the development of new business models.
Region	• CFAA as a place of interest for local and international partners to develop projects. • Increase the attractiveness of the Basque Country for research, innovation, employment and start-ups. • Intensify knowledge transfer. • Interact with society, strengthen actors and civil society.
Research	• Gather and generate experience, new knowledge and understanding from activities and management of the project (e.g., tools, techniques, approaches or processes). • Increase the impact of R&D in the scientific community.
University	• Professionalizing project management. • Promote compliance with the goals and objectives for which CFAA was created. • Securing the freedom, financial and personnel basis for research and transfer activities in the long term. • Strengthen collaboration with University in the implementation and development of projects.

Table 21 displays the critical X's of the CTQ detected for the first strategic need identified as Y1: Create and commercialise new services, product lines and technological capabilities. It must be underlined that the specific measurements necessary to meet the quality requirements were defined in advance. For each measurement, a target value was determined based on the expectations of the company (Cruz-Villazón et al., 2020).

After the information analysis process, the result was the identification of 12 strategic needs. These, in turn, led to identifying 51 operational needs (CTQs) and related to 56 drivers, in other words, the internal factors (Cruz-Villazón et al., 2020). For the innovation field, the outcome of the study concerning the strategic and operational needs are presented in Table 21 and Table 22.

Table 21: *Strategic need (Y1): Creating and marketing new services, product lines, and technological capabilities (Source: Cruz-Villazón et al., 2020)*

Operational need	**ID**	**Internal factors**	**Measurement**	**Indicator**	**Targets**
Contribute to sustainability in the creation, design and result of	X1	Strengthen strategic human resources development as a research priority	Watch over the rights and interests of the workers.	Number of complaints received VS attended. Number of wellbeing	100% complaints received vs attended. 100% wellbeing

Operational need	ID	Internal factors	Measurement	Indicator	Targets
deliverables from the projects				activities programmed VS realised	activities programmed VS realised At least one wellbeing activities programmed VS realised 100% of Safety program activities programmed VS realised 85% of participation from personnel at Safety program activities
				Number of Safety program activities programmed VS realised	

Operational need	ID	Internal factors	Measurement	Indicator	Targets
					programmed VS realised
	X2	Sustainability through creation, design and result of deliverables from the projects	Avoidance of waste	Number of good practices implemented in the use of waste	100% compliance with good practices implemented in the use of waste
			Hazard materials treatments	Kg per type of hazard materials treated	100% of hazard materials treated
				Notices received by the authority for mismanagement of hazards	Cero notices received by the authority for mismanagement of hazards
			Safety and security initiatives	Number of safety program activities	100% of safety

Operational need	ID	Internal factors	Measurement	Indicator	Targets
			to avoid accidents or incidents	programmed VS realised	program activities programmed VS realised
				Number of security program activities programmed VS realised	100% of security program activities programmed VS realised
				Number of safety events	At least 5 safety events programmed per year
				Number of security events	At least 5 security events programmed per year
Develop and implement marketing of	X3	Marketing of R&D and	Marketing campaigns of R&D and	Marketing campaigns of R&D and	At least one marketing campaigns of

Operational need	ID	Internal factors	Measurement	Indicator	Targets
the R&D service portfolio		innovation service portfolio	innovation service portfolio	innovation per innovation	R&D and innovation per innovation
Generate new usable knowledge and engineering solutions	X4	Usable knowledge and engineering solutions generated	New methods VS solutions published in scientific journal	Number of new methods VS solutions published in refereed journals.	At least 3 publication by each new methods VS solutions produced at CFAA.
				Number of new methods VS solutions presented at refereed conferences	At least 3 attendances by each new methods VS solutions produced at CFAA
			New patents	Number of new patents registered	100% of new patents registered

Operational need	ID	Internal factors	Measurement	Indicator	Targets
				Number of articles published in refereed journals regarding uses of patents.	At least 3 articles published in refereed journals.
				Number of presentations at refereed conferences regarding use of patents.	At least 3 presentations at refereed conferences.
				Number of marketing campaigns per patent	At least one marketing campaigns per patent.
Increase demand orientation in transfer	X5	Transfer-oriented demand	R&D strategy workshop participations VS Organized	Number of participations at R&D or innovation workshops	85% of participations at R&D or innovation workshops

Operational need	ID	Internal factors	Measurement	Indicator	Targets
			Innovative activities developed	Number of R&D or innovation workshop organised	At least one R&D or innovation workshop organised by CFAA
Introduce continuous innovation management	X6	Continuous innovation management introduction	Innovation projects developed	Number of projects developed characterised as "Innovative" from partners	Success rate > 80% of projects developed characterised as "Innovative" from partners
				Number of projects developed characterised as "innovative" from CFAA	Success rate > 80% of projects developed characterised as "innovative" from CFAA

A separate analysis was made for another relevant strategic need for CFAA which is Y2: Institutional support of SMEs with innovation impulses in the development of new business models (Table 22).

Table 22: *Strategic need (Y2): Institutional support of SMEs with innovation impulses in the development of new business models (Source: Cruz-Villazón et al., 2020)*

Operational needs	**Category**	**Driver**	**CTQ**	**Measurements**	**Targets**
		Formation to encourage innovation skills	Formation to develop innovation skills	Number of courses related//needed to encourage innovation skills	At least 2 courses per year
Enable and encourage talent early on	Technical	Students at CFAA doing their TFM or TFG	Students participation at CFAA	Number of new students doing TFM or TFG	At least 30 students per year
		Students at CFAA doing On-the-job formation	Students at On-the-job formation at CFAA	Number of new students doing On-the-job formation	At least 10 students per year
Expand existing cooperation	Strategic	Cooperation in strategic	Partner participation in projects	% of Partners participation in projects	70% of partners participating in

into strategic innovation partnerships		innovation partnerships			at least one project per year
			Effective cooperation development plan	Plan's implementation	30% of partners involved in the plan
			Framework agreement with all partners	Partners involved in the Framework agreement	30% of partners involved in the plan
Promote the foundation, establishment and accompaniment of spin-offs	Technical	Foundation, establishment and accompaniment of spin-offs	Spin-offs from CFAA	Number of new spin-offs from CFAA	At least 1 initiative per year
		Foundation, establishment and accompaniment of spin-offs	Initiatives enabled and encouraged	Initiatives enabled and encouraged	At least 1 initiative per year
		Business start-ups provoked	Start-ups projects activated	Number of recruitments of innovative start-	At least 1 initiative per year

		ups and joint ventures	
	Coordination and cooperation with start-up support entities (Universities, governments, private investors)	Number of new cooperation agreements with associations and business development agencies	At least 3 agreements signed per year

Chapter 9 Conclusions

In this chapter the conclusions of the thesis are discussed. For the development of this work, an SLR was conducted focusing on the concepts of Lean and Project Management. This was aimed with the objective of understanding the fundamentals of these two approaches in conjunction. Through these results the development of a Lean Project Management model became possible. Here it also highlighted the insights drawn in applying this model to the case study about the identification of KPIs in project-based organizations. This section also describes the limitations detected throughout this research, as well as a number of recommendations for future research.

This thesis was conducted with the objective of exploring and evaluating the impact of Lean Thinking as an integrated approach to Project Management. At the same time, this research is intended to investigate the application of a Lean Project Management model within project-based organizations in order to identify KPIs. The following aspects were the fundamental contents discussed and surveyed throughout this study.

- To research the components and background of the Lean approach and Project Management practices.
- To identify the elements of similarity, complementarity and differences between Lean Project Management research.
- To evaluate the impact of the Lean application on project success factors and KPIs.
- To develop a framework for the implementation of Lean in Project Management.
- To apply the Lean Project Management model developed in a case study.

As an underlying premise to the core subject of this thesis, which is Lean and its potential application to Project Management, a preliminary investigation of the independent components was carried out. Initially, the theoretical and conceptual frameworks of Lean Thinking and Project Management were analysed to identify similarities, gaps and potential contributions. Based on this, the proposed Lean Project Management model was established.

A SLR and a case study were the research strategies selected for this thesis and simple mixed method as the methodological choice. The research methodology used for the SLR was a mixture of qualitative and quantitative and conducted over a longitudinal time horizon. For the case study the time horizon was transversal and qualitative method was chosen.

The comprehensive SLR conducted makes a valuable theoretical contribution to the emerging body of research being carried out around the integration of alternative approaches to Project Management. Moreover, a comprehensive descriptive analysis was conducted from existing literature relating to Lean Project Management in particular.

Furthermore, the analysis of the applicability of the Lean Project Management was conducted examining the main features of this approach and considering ways of matching with the existing conventional approaches. In the case of this thesis, the PMBOK 6th edition was used as a framework.

Considering the main objective this thesis aimed to explore the potential applicability of the Lean approach to the management of projects. This descriptive analysis used as baseline the 103 selected papers (Appendix XX). In addition, an empirical contribution is provided by applying the Lean Project Management model to the identification of KPIs. This proposed model is useful for practitioners in their project activities.

An overview of the findings is described as well as an examination of the tools and methods of this methodological approach. The value based focus is analysed, highlighting the opportunities and challenges of the application of Lean Project Management. On a practical level, a model of Lean Project Management is developed in order to identify KPIs with the aim of monitoring and making management

decisions. This thesis has attempted to investigate the feasibility of applying Lean Thinking approach to Project Management. It was possible to demonstrate the applicability of this Lean Project Management model by implementing it in a concrete case of identifying the KPIS in a project-based organization (CFAA).

Despite the attempts to identify the causes of an under-performing Project Management, researchers have drawn the inference that the reason is "the way in which projects are managed" (Sohi et al., 2016). It is possible to conclude that Lean Project Management can be applied to improve any area of any industry that requires a shift towards continuous improvement. An increasing number of approaches are gaining popularity as alternatives to "traditional" project management, such as Lean, Six Sigma, Agile and Scrum (Tödtling et al., 2017).

Lean thinking enables to understand an organisation more deeply, raising questions that may have been overlooked arriving into conclusions of significant strategic value for the organisation (Cruz-Villazón et al. 2020). The Lean Project Management approach enhances the performance of managing projects through a clear focus on the efficiency and effectiveness of value creation based on meeting the needs of the customer (Horman & Kenley, 1996). Lean can be used in conjunction with Project Management based on the assumption that the two approaches are complementary. Both approaches share similarities in terms of their focus in improving the performance with regard to value creation.

The different sizes of projects, together with their uniqueness and complexity, requires a tailored Project Management approach (Sohi et al., 2016). Project Management need to be tailored to the current dynamic business environment (Sousa et al., 2018). Nowadays, a "traditional" Project Management approach has become ineffective (Sohi et al., 2016).

These facts fall in line with the focus of this thesis. The theories of Lean and Project Management were examined and interpreted to conceptualize an integrated framework defined as Lean Project Management. Using the Lean Project Management model, it was evaluated the process for defining KPIs in project-based organizations. Based on the knowledge gathered in the SLR, this model was developed which integrates Lean thinking, tools and principles into Project Management practices yielding as a result the Lean Project Management model.

This model was applied to a case study conducted within a R&D project-based organisation (CFAA). Following a series of steps based on lean tools and principles, the model worked as a guide for the identification of KPIs. The DMAIC methodology phases were used in order to keep an organised process flow for the model implementation (Cruz-Villazón et al. 2020).

The results of the case study provided a set of qualitative and quantitative KPIs that assess the strategic and operational needs of a project-based organization and help to understand and improve its performance criteria. Nevertheless, continuous

changes in the market or in research methodologies require that the KPIs are constantly redefined and updated to ensure that the KPIs are appropriate for the organization's current environment (Cruz-Villazón et al. 2020).

The outcomes obtained in this thesis enable project managers to better develop suitable strategies for improving Project Management practices throughout the organization. A cornerstone characteristic underlying Lean approach and Project Management practices is the emphasis on principles and a focus on value. The main change of Lean in Project Management is focused towards a flow and value generation with the objective of maximizing the added value and reducing waste in each process. The proposal of a Lean Project Management model offers a positive contribution to the improvement of project performance.

9.1 Limitations of the Research

There are limitations to this research work. The bibliographic search performed was restricted to specific keyword combinations and limited to certain databases including Scopus, ScienceDirect, WoK and Google Scholar.

Another factor that can be considered as a limitation is the date of data collection. This variable has an influence on the pace of evolution of the analysed concepts. For this study, April 2022 was the last date on which data was collected.

It is important to note that the results of this thesis are limited to the environment of project-based organisations specifically RTD. Furthermore, it should also be considered the limitation of the region, as the case study was done in a company being located within the Basque Country, Spain.

Furthermore, the Project Management approach used for this thesis was based on the PMBOK Guide 6th edition. During the development of the research the PMBOK 7th edition was released, therefore the new version is not included in the present thesis.

Research has not been done on broader developments of the Lean approach such as those related to sustainability (Lean and Green), or Lean coupled with Agile systems (Leagile), or the Lean insights into Business Models (Lean Canvas). These topics are mentioned throughout the thesis but not fully discussed as they fall out of the scope of this thesis.

9.2 Future Research Recommendations

Future research is recommended for applying the Lean Project Management model to other types of projects across different sectors. New Lean Project Management methods and techniques are required to be developed, providing the starting point for further research in this domain.

For this thesis only a few methods and tools, on the basis of the proposed Lean Project Management model, were applied in an empirical way to a case study. Further research is recommended to tailor and apply other Lean Project Management techniques such as Lean Canvas to case studies.

The scope of this research was limited to proposing a model for the identification of KPIs using the Lean approach, therefore for future research, it is suggested to continue with the following actions of validating, communicating, reporting, and controlling the adequacy of the KPIs. "Visual management" is a suitable technique to manage the quality of the KPIs. For managers and project managers, the use of KPIs "dashboards" are recommended during to report, monitor, and control the KPIs (Cruz-Villazón et al. 2020). Since the focus of this study is on the identification and categorisation of KPIs, the validation, adequacy, and control of KPIs are recommended as future research in the Conclusions section (Cruz-Villazón et al. 2020).

Finally, though the result of this research is valuable for project-based organizations in general, the focus of this study is particularly for companies that are uncertain about the correct definition of KPIs, or whose path is still unclear. The scope of this thesis does not include the analysis of corporate strategy and culture, which is recommended to be explored as future research (Cruz-Villazón et al. 2020).

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Appendix A

Selected papers on Lean Project Management for the Systematic Literature Review

Source	Title	Source	Country	Institution	Type of paper
Abuhejleh et al. (2016)	Using lean management to leverage innovation in healthcare projects: Case study of a public hospital in the UAE	BMJ Innovations	United Arab Emirates	British University in Dubai	Case study
Ahn et al. (2007)	Project-based knowledge management system for lean construction	Lean Construction: A New Paradigm for Managing Capital Projects - 15th IGLC Conference	South Korea	Seoul National Univ.	Research paper
Albuquerque et al. (2020)	Lean product development and agile project management in the construction industry	Rege-Revista De Gestao	Brazil	University of São Paulo	Case study

Alizadehsalehi et al. (2019)	BIM/MR-Lean Construction Project Delivery Management System	IEEE Technology & Engineering Management Conference (TEMSCON)	USA	Northwestern University Evanston	Research paper
Amran et al. (2019)	Evaluating Storage Tank Cap 10000L Manufacturer by Using Lean Project Management	IOP Conference Series: Materials Science and Engineering	Indonesia	University of Trisakti	Case study
Anholon & Sano (2016)	Analysis of critical processes in the implementation of lean manufacturing projects using project management guidelines	International Journal of Advanced Manufacturing Technology	Brazil	State University of Campinas	Research paper
Ansah et al. (2016)	Lean construction: An effective approach for project management	ARPN Journal of Engineering and Applied Sciences	Malaysia	Universiti Malaysia Pahang	Research paper
Antony et al. (2021)	Using Six Sigma DMAIC for Lean project management in education: a case study in a German kindergarten	Total Quality Management & Business Excellence	United Arab Emirates UK	Khalifa University Heriot-Watt University,	Case study

			India New Zeland	Edinburgh Indian School of Business Massey University	
Ariyanti et al. (2021)	Implementation of lean construction and critical chain project management (CCPM) for waste management and work estimation on the Ciawi dam construction project	IOP Conference Series: Earth and Environmental Science	Indonesia	Bina Nusantara University	Case study
Ballard & Howell (2003)	Lean project management	Building Research and Information	USA	Lean Construction Institute, University of California at Berkeley	Conceptual paper
Baptista et al. (2014)	Lean and efficient project management: new concepts and tools.	International Conference on Project Management and Scheduling	Brazil	Institute of Science and Innovation in Mechanical and	Case study

				Industrial Engineering	
Bascoul et al. (2018)	Construction Project Complexity as Addressed in Traditional versus Lean Project Management Literature	Construction Research Congress 2018	USA	University of California at Berkeley, Berkeley National Laboratory	Research paper
Beauregard (2015)	Surprises and cost overruns: A lean risk management approach to reduce surprises and address cost overruns in aerospace product development projects	International Annual Conference of the American Society for Engineering Management 2015, ASEM 2015	Canada	École De Technologie Supérieure	Case study
Biskupska & Ratnayake (2019)	On the Need for Effective Lean Daily Management in Engineering Design Projects: Development of a Framework	IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)	Norway	University of Stavanger	Case study

Bonnal & Braesch (2013)	Can a deliverable-oriented: Project management approach be the foundations jor a lean approach?	Journal of Modern Project Management	Switzerland, France	Université de Savoie	Case study
Boudouh et al. (2013)	Project management and lean engineering: An industrial application	Journal of Modern Project Management	France	Laboratoire IRTES	Case study
Brioso (2015a)	Teaching Lean Construction: Pontifical Catholic University of Peru Training Course in Lean Project & Construction Management	Procedia Engineering	Peru	Pontifical Catholic University of Peru	Case study
Brioso (2015b)	Integrating ISO 21500 Guidance on Project Management, Lean Construction and PMBOK	Procedia Engineering	Peru	Pontifical Catholic University of Peru	Research paper
Bryde & Schoolmaster (2013)	Applying Lean principles to a building refurbishment project: experiences of key stakeholders	Construction Management and Economics	UK	Liverpool Business School	Research paper

Bungardi et al. (2021)	Critical path method and lean design management applied in design of solar energy projects: a comparison study	Series-Applied Mathematics Mechanics and Engineering	Romania	Technical University of Cluj-Napoca	Case study
Cesarotti et al. (2019)	The evolution of Project Management (PM): How Agile, Lean and Six Sigma are changing PM	Journal of Modern Project Management	Italy	University of Rome Tor Vergata	Research paper
Chen et al. (2007)	Interface management-a facilitator of lean construction and agile project management	Lean Construction: A New Paradigm for Managing Capital Projects - 15th IGLC Conference	USA	Virginia Polytechnic Institute	Research paper
Chen (2012)	Study on the Application of Lean Construction Supply Chain Management in EPC Project	Applied Mechanics and Materials	China	Qingdao Technological University	Research paper
Cruz et al. (2020)	Traditional, agile and lean project management: A systematic literature review	The Journal of Modern Project Management	Portugal	University of Minho	Literature review

Cruzado-Ramos & Brioso (2020)	Sustainability performance evaluation in building projects by integrating lean and sustainable management using the Delphi method	Annual Conference of the International Group for Lean Construction (IGLC28)	Peru	Pontifical Catholic University of Peru	Case study
Dabestani et al. (2017)	Proposing a model for evaluating lean project management performance using grounded theory	International Journal of Productivity and Quality Management	Iran	Tarbiat Modares University, University of Isfahan	Research paper
Dallasega et al. (2020)	BIM, Augmented and Virtual Reality empowering Lean Construction Management: a project simulation game	Procedia manufacturing	Italy	University of Bozen-Bolzano	Case study
Demir et al. (2012)	Re-Conceptualizing Agile for lean construction: The case for "Agilean" project management	Association of Researchers in Construction Management, ARCOM 2012 - Proceedings of the 28th Annual Conference	UK	Liverpool John Moores University	Research paper

Deshpande et al. (2012)	Lean Techniques in the Management of the Design of an Industrial Project	Journal of Management in Engineering	USA	Syracuse Univ., Univ. of Cincinnati	Research paper
Dowson et al. (2019)	Lean Project Management as a facilitator of organisational learning	BAM2019 Conference Proceedings. British Academy of Management	UK, Germany	Liverpool John Moores University	Research paper
Dursun et al. (2020)	An intuitionistic fuzzy cognitive map approach to evaluate success factors of lean six sigma project management methodology	Advances in Intelligent Systems and Computing	Turkey	Galatasaray University	Case study
Elias (2016)	Stakeholder analysis for Lean Six Sigma project management	International Journal of Lean Six Sigma	New Zealand	Victoria University of Wellington	Research paper
Erusta & Sertyesilisik (2019)	An Investigation into Improving Occupational Health and Safety Performance of Construction Projects Through Usage of BIM for Lean Management.	Eurasian BIM Forum	Turkey	Istanbul Technical University	Research paper

Fitzgerald et al. (2014)	Evidence-Based Decision Making in Lean Software Project Management	36th International Conference on Software Engineering, ICSE Companion 2014 - Proceedings	Ireland, Poland	University of Limerick	case study
Gabriel (1997)	Lean approach to project management.	International Journal of Project Management	UK	Gabriel Project Consultants	Conceptual paper
Gomez & Bahtiar (2008)	Mechanism for introducing lean construction project management principles and concepts through self-directed learning	IGLC Annual Conference of the International Group for Lean Construction	Malaysia	University Tun Hussein Onn Malaysia (UTHM)	Technical paper
Gupta et al. (2022)	Utilization of lean project management principles and health informatics to reduce operating room delays in a vascular surgery practice	The American Journal of Surgery	USA	University of Colorado	Case study
Hamerski et al. (2019)	Combining lean and agile project management in a multi-project environment: Case study in a retail company	IGLC Annual Conference of the International Group for Lean Construction, 2019	Brazil	Federal University of Rio Grande do Sul (UFRGS)	Case study

Han & Wang (2015)	The Research of Project Quality Management Model Based on Lean Construction	MSETASSE International Conference on Management Science, Education Technology, Arts, Social Science and Economics (MSETASSE 2015)	China	Xi'an University of Architecture and Technology	Research paper
Heravi et al. (2021)	Integrating the production and the erection processes of pre-fabricated steel frames in building projects using phased lean management	Engineering, Construction and Architectural Management	Iran	University of Tehran	Research paper
Herrera et al. (2021)	Analyzing the Association between Lean Design Management Practices and BIM Uses in the Design of Construction Projects	Journal of Construction Engineering and Management	Chile, Spain	Pontificia Universidad Católica de Chile, Universitat Politècnica de València	Technical paper

Herrera et al. (2020)	An Assessment of Lean Design Management Practices in Construction Projects	Sustainability	Chile, Spain	Pontificia Universidad Católica de Chile, Universitat Politècnica de València	Case study
Howell & Koskela (2000)	Reforming project management: the role of lean construction	8th Annual Conference of the International Group for Lean Construction	UK	University of Huddersfield Repository	Conceptual paper
Hozak & Olsen (2014)	Lean psychology and the theories of "Thinking, Fast and Slow".	International Journal of Lean Six Sigma	USA	Coastal Carolina University, California Polytechnic State University	Conceptual paper

Iberico-Tafur et al. (2020)	Management projects model to reduce lead time of base station telecom construction in SME based on lean focus and agility.	International Conference on Human Interaction and Emerging Technologies	Peru, Spain	Universidad Peruana de Ciencias Aplicadas, Universidad Rey Juan Carlos	Case study
Iqbal (2015)	Leading Construction Industry to Lean-Agile Project Management	PMI Global Congress Proceedings	USA	SysComp International Private Limited	Research paper
Iskoskov & Sosunova (2013)	Using lean management tools at different stages of the innovation project	Middle East Journal of Scientific Research	Russia	Tolyatti State University	Research paper
Juanfang & Xing (2011)	Notice of Retraction: Application of lean construction in quality management of engineering projects	2011 International Conference on E-Business and E-Government, ICEE2011 - Proceedings	China	Wuhan University	Research paper

Kemmer & Koskela (2012)	Developing a lean model for production management of refurbishment projects	IGLC 2012 - 20th Conference of the International Group for Lean Construction	UK	University of Salford	Research paper
Kestle et al. (2011)	Integration of Lean Design and Design Management and its Influence on the Development of a Multidisciplinary Design Management Model for Remote Site Projects	Architectural Engineering and Design Management	New Zealand	Unitec Institute of Technology, University of Canterbury	Case study
Krishnan et al. (2020)	Developing a Hybrid Approach for Lean Six Sigma Project Management: A Case Application in the Reamer Manufacturing Industry	IEEE Transactions on Engineering Management.	India	Amity University	Case study
Kulinich et al. (2021)	Application of Project Management: Lean Technologies and Saving Manufacturing (Aspects of Management and Public Administration	International Journal of Computer Science & Network Security	Ukraine	Lviv Polytechnic National University, Poltava State Agrarian Academy,	Research paper

				Taras Shevchenko National University of Kyiv, National Academy of Public Administration	
Lalmi et al. (2022)	Synergy between Traditional, Agile and Lean management approaches in construction projects: bibliometric analysis	Procedia Computer Science	Algeria Portugal	University of Constantine, University of Coimbra	Research paper
Lee et al. (2010)	Lean design management in an infrastructure design-build project: A case study	Challenging Lean Construction Thinking: What Do We Think and What Do We Know? - 18th Annual Conference of the International Group for Lean Construction, IGLC 18	USA	University of California	Case study

Lekan & Segunfunmi (2018)	Lean concept thinking-based quality management model for residential building construction projects	International Journal of Mechanical Engineering and Technology	Nigeria	Covenant University	Case study
Li & Ma (2014)	The application of lean management in power engineering projects	Advanced Materials Research	China	Dianli University	Research paper
Monyane et al. (2018)	Identification of lean opportunities in South African public-sector projects cost management framework	IGLC 2018 - Proceedings of the 26th Annual Conference of the International Group for Lean Construction: Evolving Lean Construction Towards Mature Production Management Across Cultures and Frontiers	South Africa	Central Univ. of Technology, Nelson Mandela University	Case study
Mostafa et al. (2020)	Lean and agile project management concepts in the project management profession	Project Management Research and Practice	Australia	Griffith University	Research paper

Mota et al. (2019)	Lean design management in a major infrastructure project in UK	IGLC 27th Annual Conference of the International Group for Lean Construction, IGLC 2019	UK, Brazil	Logikal Projects, Federal University of São Carlos, University of Huddersfield	Case study
Oliveira de et al. (2020)	Lean and agile project management: An overview of the literature exploring complementarities	The Journal of Modern Project Management	Brazil	University of São Paulo	Literature review
Qi et al. (2010)	Study on integration and management system of schedule in large complex construction engineering projects based on lean construction	IFITA 2010 International Forum on Information Technology and Applications, IFITA 2010	China	Huaqiao University,	Case study
Qiu (2011)	Uncertainty in Project Management Based on Lean Construction Implementation	Advanced Materials Research	China	Wuhan University of Technology	Research paper

Rashid & Heravi (2012)	A lean management approach for power plant construction projects: Wastes identification and assessment	IGLC 2012 - 20th Conference of the International Group for Lean Construction	Iran	University of Tehran	Research paper
Rebaiaia & Vieira (2014)	Integrating PMBOX standards, lean and agile methods in project management activities	International Journal of Computer Applications	Canada	Laval University, University of Quebec at Trois-Rivières	Research paper
Reusch & Reusch (2013)	How to develop Lean Project Management	IDAACS Proceedings of the 2013 IEEE 7th International Conference on Intelligent Data Acquisition and Advanced Computing Systems, IDAACS 2013	Germany	University of Applied Sciences and Arts Dortmund	Conceptual paper
Reusch & Dechange (2013)	Lean project management	International Scientific Conference on Project	Germany	University of Applied Sciences and	Conceptual paper

		Management in the Baltic Countries		Arts Dortmund	
Rico (2010)	Lean and Agile Project Management: For Large Programs and Projects	International Conference on Lean Enterprise Software and Systems	USA	No info	Research paper
Riis (1993)	Lean project management	International Journal of Project Management	Denmark	University of Aalborg	Conceptual paper
Rosli et al. (2020)	The effects of suitability and acceptability of lean principles in the flow of waste management on construction project performance	International Journal of Construction Management	Malaysia	Universiti Malaysia Pahang	Case study
Rozenfeld et al. (2007)	Construction job safety analysis in support of lean project management	CME 2007 Conference - Construction Management and Economics: 'Past, Present and Future'	Israel	Israel Institute of Technology	Case study

Saldanha et al. (2019)	Improvement of Project Management Processes and Practices Aided by Lean Tools in a Metalworking Company	VISION 2025: Education Excellence and Management of Innovations through Sustainable Economic Competitive Advantage	Portugal	Universidade do Minho, ETMA Metalparts	Case study
Sanchez-Losado (2012)	Project management models: Lean thought Project Management	DYNA	Spain	AENA Aeropuertos	Model
Sbiti et al. (2021)	Toward BIM and LPS Data Integration for Lean Site Project Management: A State-of-the-Art Review and Recommendations	Buildings	France	LINEACT CESI, ENGIE SOLUTIONS	Literature review
Sertyesilisik (2014)	Lean and Agile Construction Project Management: As a Way of Reducing Environmental Footprint of the Construction Industry	Optimization and Control Methods in Industrial Engineering and Construction	England, Turkey	Liverpool John Moores University, Istanbul Technical University	Research paper

Silva et al (2021)	Interdisciplinary Framework: A Building Information Modelling Using Structural Equation Analysis in Lean Construction Project Management	MMBD Modern Management Based on Big Data II and Machine Learning and Intelligent Systems III: Proceedings of MMBD 2021 and MLIS 2021	Philippines	Mapúa University	Research paper
Simon & Canacari (2012)	A practical guide to applying lean tools and management principles to health care improvement projects.	AORN journal	USA	Beth Israel Deaconess Medical Center	Case study
Sohi et al. (2016)	Does lean & agile project management help coping with project complexity?	Procedia-social and behavioral sciences	The Netherlands	Delft University of Technology	Research paper
Sosa & De La Torre (2021)	Feasibility of Stakeholder Management to improve Integration and Communication using Big Room, Lean Construction, PMBOK	IGLC Proc. 29th Annual Conference of the International Group for Lean Construction (IGLC29)	Peru	Universidad Peruana de Ciencias Aplicadas	Research paper

	and PRINCE2 in Multifamily Projects in Times of Change.				
Sousa et al. (2018)	Implementation of project management and lean production practices in a SME Portuguese innovation company	Procedia computer science	Portugal	University of Minho	Research paper
Sreedharan & Sunder (2018)	A novel approach to lean six sigma project management: a conceptual framework and empirical application	Production Planning & Control	India	Indian Institute of Technology	Conceptual paper
Stichhauerova & Pelloneova (2018)	Evaluating the efficiency of lean management projects using data envelopment analysis	MM Science Journal	Czech Republic	Technical University of Liberec	Conceptual paper
Sunder (2016)	Lean six sigma project management - A stakeholder management perspective	TQM Journal	India	Indian Institute of Technology	Research paper
Sundqvist et al. (2017)	Lean in project-based organizations.	24th EurOMA conference	Sweden	Lulea University of Technology	Case study

Tenera & Pinto (2014)	A Lean Six Sigma (LSS) project management improvement model	Procedia-Social and Behavioral Sciences	Portugal	Universidade Nova de Lisboa	Case study
Tödtling et al. (2017)	Managing New Product Development Projects Using Lean Startup Approach	Proceedings of 2nd International Scientific Conference LEAN Spring Summit 2017	Croatia	University of Zagreb	Case study
Usman & Rendy (2017)	Toward Lean Construction through Critical Chain Project Management and Root Cause Analysis in a Construction Project	ICOI International Conference of Organizational Innovation (ICOI 2017)	Indonesia	Universitas Airlangga Indonesia	Case study
Uusitalo et al. (2019)	Applying Level of Detail in a BIM-Based Project: An Overall Process for Lean Design Management	Buildings	Finland, Brazil	Aalto University, Racional Engenharia Ltda	Case study
Veretennikova & Vaskiv (2018)	Application of the Lean startup methodology in project management at launching new innovative products	IEEE 13th International Scientific and Technical Conference on Computer	Ukraine	Lviv Polytechnic National University	Research paper

		Sciences and Information Technologies (CSIT)			
Verrier et al. (2013)	Combining organizational performance with sustainable development issues: the Lean and Green project benchmarking repository.	Journal of Cleaner Production	France	University of Strasbourg	Case study
Vickranth et al. (2019)	Application of lean techniques, enterprise resource planning and artificial intelligence in construction project management	International Journal of Recent Technology and Engineering	India	Koneru Lakshmaiah Education Foundation	Research paper
Vila-Parrish & Raubenheimer (2012)	Integrating Project Management, Lean-Six Sigma, and Assessment in an Industrial Engineering Capstone Course	ASEE Annual Conference and Exposition, Conference Proceedings	USA	North Carolina State University	Case study
Vrincut et al. (2017)	Lean IT as a means for project management improvement for romanian IT projects	IE 2017 - The 16th International Conference on Informatics in Economy	Romania		Case study

Wu et al. (2019)	Improving the Efficiency of Highway Construction Project Management Using Lean Management	Sustainability	UK China	Nottingham University Business School China, UK	Case study
Xiaolin (2007)	Study on lean construction project cost management	ICCREM Proceedings of International Conference on Construction & Real Estate Management, VOLS 1 AND 2	China		Research paper
Ximenes et al. (2015)	Software project management combining agile, lean startup and design thinking	Design, user experience, and usability: Design discourse	Brazil	Universidade Federal de Pernambuco	Case study
Xing et al. (2021)	Implementing lean construction techniques and management methods in Chinese projects: A case study in Suzhou, China	Journal of cleaner production	Australia, China	Western Sydney University, Xi'an Jiaotong-Liverpool University	Case study

Yan & Peng (2014)	The control of engineering project cost management of construction enterprise based on lean model experimental analysis	ICICTA 2014 7thnternational Conference on Intelligent Computation Technology and Automation (IEEE)	China	Wuhan University of Engineering Science	Research paper
Yang & Qiu (2006)	Project Life-Cycle Lean Value management and its application	ICIM 2006: Proceedings of the Eighth International Conference on Industrial Management	China	Beijing University of Science & Technology	Case study
Yang et al. (2008)	Lean principle and value stream mapping/analysis (vsm/a) for project management		China	University of Science and Technology Beijing	Case study
Yordanova (2017)	Knowledge transfer from lean startup method to project management for boosting innovation projects' performance	International Journal of Technological Learning, Innovation and Development	Bulgaria	University of National and World Economy	Case study
Zhang & Su (2008)	Study on Project Process Management Based on Lean Construction	Proceeding of 2008 International Conference on Construction &	China		Research paper

		Real Estate Management, Vols 1 and 2			
Zhong & Chen (2011)	Principles of Sustainable Construction Project Management Based on Lean Construction	Advanced Materials Research	China	Zhejiang Industry Polytechnic College	
Zimmer et al. (2008)	Case study: Lean supply chain management in construction projects	Proceedings of IGLC16: 16th Annual Conference of the International Group for Lean Construction	USA	University of Cincinnati	Case study

Appendix B

Journals of the Lean Project Management papers and their frequency of publication

Journal name	Abbreviation	Frequency
Academy of Management Review	AMR	2
Advanced Materials Research	AMR	3
Advances in Intelligent Systems and Computing	AISC	1
AORN journal	AORN	1
Applied Mechanics and Materials	AMM	1
Architectural Engineering and Design Management	AEDM	1
ARPN Journal of Engineering and Applied Sciences	ARPNJEAS	1
BMJ Innovations	BMJI	1
Building Research and Information	BRI	1
Buildings	Buildings	2

Construction Management and Economics	CME	1
DYNA	DYNA	1
Engineering, Construction and Architectural Management	ECAM	1
International Journal of Advanced Manufacturing Technology	IJAMT	1
International Journal of Computer Applications	IJCA	1
International Journal of Computer Science & Network Security	IJCSNS	1
International Journal of Construction Management	IJCM	1
International Journal of Lean Six Sigma	IJLSS	2
International Journal of Mechanical Engineering and Technology	IJMET	1
International Journal of Productivity and Quality Management	IJPQM	1
International Journal of Project Management	IJPM	2
International Journal of Recent Technology and Engineering	IJRTE	1
International Journal of Technological Learning, Innovation and Development	IJTLID	1
Journal of Cleaner Production	JCP	2
Journal of Construction Engineering and Management	JCEM	1

Journal of Management in Engineering	JME	1
Journal of Modern Project Management	JMPM	5
Middle East Journal of Scientific Research	MEJSR	1
MM Science Journal	MMSJ	1
Optimization and Control Methods in Industrial Engineering and Construction	OCMIEC	1
Procedia Computer Science	PCS	1
Procedia Engineering	PE	1
Production Planning & Control	PPC	1
Project Management Research and Practice	PMRP	1
Rege-Revista De Gestao	RRDG	1
Sustainability	Sustainability	2
The American Journal of Surgery	TAJS	1
Total Quality Management & Business Excellence	TQMBE	1
Total Quality Management Journal	TQMJ	1

Appendix C

Conferences of the Lean Project Management papers and their frequency of publication

Conference name	Abbreviation	Frequency
Acta Technica Napocensis Series-Applied Mathematics Mechanics and Engineering	ATSAMME	1
Annual Conference and Exposition, Conference Proceedings	ASEE	1
Annual Conference of the International Group for Lean Construction	IGLC	13
Association of Researchers in Construction Management	ARCOM	1
British Academy of Management	BAM	1
Construction Management and Economics	CME	1
Construction Research Congress	CRC (ASCE)	1
Design, User Experience, and Usability	DUXU	1
Eurasian BIM Forum	EBF	1
European Operations Management Association	EurOMA	1

International Annual Conference of the American Society for Engineering Management	ASEM	1
International Business Information Management Association Conference	IBIMA	1
International Conference of Organizational Innovation	ICOI	1
International Conference on Construction & Real Estate Management	ICCREM	2
International Conference on E-Business and E-Government	ICEE	1
International Conference on Eco Engineering Development	ICEED	1
International Conference on Human Interaction and Emerging Technologies	IHIET	1
International Conference on Industrial Engineering and Engineering Management	IEEM (IEEE)	1
International Conference on Industrial Management	ICIM	1
International Conference on Informatics in Economy	IE	1
International Conference on Intelligent Computation Technology and Automation	ICICTA (IEEE)	1
International Conference on Intelligent Data Acquisition and Advanced Computing Systems	IDAACS (IEEE)	1
International Conference on Lean Enterprise Software and Systems	LESS	1
International Conference on Management Science, Education Technology, Arts, Social Science and Economics	MSETASSE	1

International Conference on Project Management and Scheduling	ICPMS	1
International Conference on Software Engineering	ICSE (IEEE)	1
International Forum on Information Technology and Applications	IFITA	1
International Scientific and Technical Conference on Computer Sciences and Information Technologies	CSIT (IEEE)	1
International Scientific Conference Lean	ISCL	1
International Scientific Conference on Project Management in the Baltic Countries	ISCPMBC	1
International Seminar on Industrial Engineering and Management	ISIEM	1
Machine Learning and Intelligent Systems	MLIS	1
Modern Management Based on Big Data	MMBD	1
PMI Global Congress Proceedings	PMI - GCP	1
Procedia Computer Science	PCS	1
Procedia Engineering	PE	1
Procedia Manufacturing	PM	1
Procedia-Social and Behavioral Sciences	PSBS	2
Technology & Engineering Management Conference	TEMSCON (IEEE)	1