T.C.
ANKARA YILDIRIM BEYAZIT UNIVERSITY
SOCIAL SCIENCES INSTITUTE

PROJECT MANAGEMENT IN THE ERA OF AI: REVIEW AND ANALYSIS

MASTER'S THESIS

Ahmet Furkan ÇİFTÇİ

MANAGEMENT INFORMATION SYSTEMS PROGRAMME

Ankara, 2022

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Doç. Dr. Derya FINDIK
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APPROVAL PAGE

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Ahmet Furkan ÇİFTÇİ

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ABSTRACT

Project Management in the Era of AI: Review and Analysis

Artificial Intelligence (AI) is expected to boost the performance of certain professions, while potentially destroying a few of them. Project Management (PM), as a profession, will not be exempt from this trend, thus it's worth speculating on what implications AI may have on the field in the future. This study aims to contribute to the PM domain from three perspectives, First of all; this study reviews the domain with the integrative literature review technique, which is a novel literature review technique. Secondly, this study explores the effects of AI on PM as a profession from a bibliometric analysis perspective. Lastly, this study maps the possible evolution of the PM domain. A map of the evolution of the domain is crucial for decision-makers since it is vital in terms of efficiency and organizational purposes. From this perspective, policy implications of AI-augmented PM on different levels are analyzed, in terms of business and managers, and its implications at the national level. The findings demonstrated that AI will become an integral element of future PM practice and will have an immediate impact on the PM profession. It is anticipated that while AI is not likely to replace human-driven project management, it will have a significant impact on cost, scheduling, and risk management, according to the literature.

Keywords: Artificial Intelligence, bibliometric analysis, integrative literature review, Project Management, Thematic Evolution

ÖZET

Yapay Zeka Çağında Proje Yönetimi: İnceleme ve Analiz

Günümüzde Yapay Zeka'nın (AI) bazı mesleklerin performansını artırması beklenirken, bazılarını ise ortadan kaldırması beklenmektedir. Bir meslek olarak Proje Yönetimi'nin (PM) de bu trendden muaf olmayacağı öngörülmektedir, bu nedenle AI'nın gelecekte sahada ne gibi etkileri olabileceği konusunda spekülasyon yapmaya değer. Bu çalışma, Proje Yönetimi alanına üç açıdan katkı sağlamayı amaçlamaktadır. Öncelikle; Bu çalışma, yeni bir literatür tarama tekniği olan bütünleştirici literatür tarama tekniği ile alanı incelemektedir. İkinci olarak, bu çalışma, bibliyometrik analiz perspektifi ile bir meslek olarak AI'nın PM üzerindeki etkilerini araştırmaktadır. Son olarak, bu çalışma PM alanının olası gelişimini haritalamaktadır. Verimlilik ve organizasyonel amaçlar açısından hayati önem taşıdığından, karar vericilerin bir mesleğin geleceğini ve gelişimini haritalaması çok önemlidir. Bu nedenle, çalışmada yapay zeka ile güçlendirilmiş proje yönetiminin farklı seviyelerdeki politika sonuçları, işletme düzeyinde, yöneticiler düzeyinde ve ulusal düzeyde analiz edilmiştir. Bu çalışmanın sonucunda elde edilen bulgular, yapay zekanın gelecekteki proje yönetimi uygulamalarının ayrılmaz bir parçası olacağını ve proje yönetimi mesleği üzerinde anında bir etkisi olacağını göstermiştir. Yapay zekanın insan odaklı proje yönetiminin yerini alması muhtemel olmasa da, literatüre göre maliyet, zamanlama ve risk yönetimi üzerinde önemli bir etkiye sahip olacağı tahmin edilmektedir.

Anahtar Kelimeler: Yapay Zeka, bibliyometrik analiz, bütünleştirici literatür taraması, Proje Yönetimi, Tematik Gelişim

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AI	Artificial Intelligence
ANN	Artificial Neural Network
BC	Betweenness Centrality
CC	Closeness Centrality
CI	Computational Intelligence
CPM	Critical Path Method
DSS	Decision Support Systems
ES	Earned Schedule
EVA	Earned Value Analysis
EVM	Earned Value Management
EU	European Union
II	Inclusion Index
IS	Information Systems
IT	Information Technologies
ISI	Institute for Scientific Information
IDSS	Intelligent Decision Support System
KPI	Key Performance Indicator
KADS	Knowledge Acquisition Data System
KBS	Knowledge Based Systems
LSTM	Long Short Term Memory
ML	Machine Learning
NGCS	Normalized Global Citation Score
PERT	Program Evaluation and Review Technique
PM	Project Management
PMBOK	Project Management Body of Knowledge

PMI	Project Management Institute
SSCI	Social Sciences Citation Indexed
SI	Stability Index
SVM	Support Vector Machines
TC	Total Citations
WoS	Web of Science

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1. INTRODUCTION

Project Management Institute (PMI) defines Project Management as “the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements” (PMI, 2017). The need for a Project Management structure occurs out of inefficiencies, not only in the management of resources but also to increase quality and performance while minimizing the cost. Hussain & Wearne claims that the main problems faced in project management are in terms of organization, time, and resources (Hussain & Wearne, 2005). In addition, according to the survey conducted by Accenture, “Project Managers spend the bulk of their time (%56) on coordination and control tasks—those most expected to fall to intelligent systems in the future” (Kolbjørnsrud et al., 2016a).

Artificial Intelligence (AI) is a motor theme in the business & management domain. Every sector aims to benefit from AI, and project management as a labor-intensive work, is a promising domain that can benefit from AI in various ways, especially in terms of efficiency, quality management, and cost minimization. Several AI solutions address Project Management issues in literature, such as using chat-bots for handling human interaction (Cīrule & Bērziša, 2019) and using machine learning algorithms for critical success factors identification and project success prediction (Magaña Martínez & Fernandez-Rodriguez, 2015). Although there are vast solutions provided by AI for Project Management, a comprehensive literature review and an analysis of how AI will affect Project Management as a profession is absent in the field and needs to be addressed. For this purpose, an integrative literature review technique is chosen to integrate PM and AI domains to generate new frameworks and perspectives (Torraco, 2016).

By the mid-twentieth century, project managers had begun to advocate for project management to be recognized as a profession. Obtaining agreement on the substance of the Project Management Body of Knowledge (PMBOK) was one component of this task, which is defined by the Project Management Institute (PMI) as a word for the expertise gained via the project management profession (Project Management Institute, 2017). However, in the case of a shift of paradigms, especially in terms of the creation process, there are always ups and downs. It is a fact that AI is boosting the performance of certain professions while replacing (or

potentially will) or diminishing some of them. Project management will not be exempt from this trend, thus it's worth speculating on what implications AI may have on the field in the future. Beyond speculation, as key researchers in the domain suggested, “There is still a lack of scientific research in the field of AI regarding project management” (Fridgeirsson et al., 2021).

The main research question of this study is “How Artificial Intelligence affects Project Management as a Profession?” To examine the question further, three subquestions are asked and answered. These are, “Will AI replace Project Managers?”, “How has PM evolved through time?” and “What is the future of PM in the light of the advancement of AI?”.

This study aims to contribute to the domain from three perspectives, First of all; this study reviews the domain with the integrative literature review technique, which is a novel literature review technique. The integrative literature review technique is useful for assembling and evaluating individual works of literature (PM and AI in this study) to identify not only the insights and perspectives they provide, but also the shortcomings, exclusions, inaccuracies, and other issues that are unavoidable with recently published literature on a new concept. Project management is not a new concept, however, with recent developments in technology and the job market, it is redefined. Project management originated from the construction sector and the Great Wall of China, the Pyramids of Giza, and the Coliseum are considered the first examples of successful project management (Seymour & Hussein, 2014). However, today in the 21st century PM has a completely new and broader perspective. Hence, there is a need for an integrative review of the domain to define it in its new form and give insights into recent developments in the domain.

Secondly, this study aims to explore the effects of AI on project management as a profession from a bibliometric analysis perspective. Numerous researchers have examined project management in light of recent advancements in AI. In their paper, Kolbjørnsrud et al. explored the effect of AI in terms of management is examined and a total redefinition is foreseen. (Kolbjørnsrud et al., 2016b). Ong & Uddin also discussed and revealed the existing status of Data Science and Artificial Intelligence for the Project Management domain (Ong & Uddin, 2020). However, these studies are using surveys and do not include a complete review of the domain. To contribute to the literature with a complete review, this study provides a bibliometric analysis and an integrative literature review to project management. Bibliometric analysis is conducted under three sections, bibliometric performance analysis, network analysis and science mapping. In the science mapping section of the bibliometric analysis, the domain

is analyzed with bibliographic coupling, co-citation analysis, co-word analysis and co-authorship analysis methods.

Lastly, this study is conducted to map the possible evolution of the project management domain. Decision-makers need a map for the evolution of the domain since it is vital in terms of efficiency and organizational purposes. In addition, this kind of mapping also provides a starting point for further research. For determining the key broad thematic areas of the PM domain, its origin and interconnections, based on the findings of performance analysis and science mapping, thematic evolution analysis is used in this study.

According to the findings of the study, the implications of AI on PM at different levels, in terms of managers, business, and Turkey as a national example are provided at the end of the study.

This study is conducted under six chapters, “Introduction”, “Literature Review”, “Data Management”, “Methodology, Analytical Framework and Analysis”, “Conclusion” and “Policy Implications”.

2. LITERATURE REVIEW

A literature review examines books, academic papers, and any other sources related to a certain subject, field of study, or theory and offers a description, summary, and critical assessment of these works concerning the research problem under examination (Fink, 2014). There are various methods developed by researchers from different disciplines for reviewing the literature. Snyder categorized literature review techniques under three different categories; systematic, semi-systematic, and integrative (Snyder, 2019). A systematic review is "an attempt to collate all empirical evidence that fits pre-specified eligibility criteria to answer a specific research question" (Liberati et al., 2009). Semi-systematic (narrative) review is intended for topics that have been developed and investigated in different ways by numerous groups of academics from various fields, preventing a full systematic review process (Snyder, 2019). The integrative literature review is a unique type of study that develops new knowledge about a topic by evaluating, criticizing, and synthesizing representative literature on the issue in an integrated manner, resulting in new frameworks and views on the topic (Torraco, 2016).

In this study, amongst the different approaches to literature reviewing, the integrative literature review technique is chosen and conducted, and it is categorized with the findings of bibliometric analysis methods. Since the project management topic has been investigated by a vast number of experts from different fields, (namely construction management, software development, business analytics, etc.) the best approach for the topic was to conduct an integrative literature review. The guide of Richard Torraco is used in this systematic review to ensure its transparency and completeness (Torraco, 2016).

Laboratories and literature are regarded as two strong instruments for scientists to use to change the world—they construct sophisticated worlds in laboratories and enforce them on paper. (Latour, 1987) As Latour suggested, scientists place a high value on words. Although science cannot be reduced to text alone, words in a text remain an important source for research. Following the words, rather than following the researchers individually to see how they affect the world, is a useful technique to map the dynamics of science (Qin, 1999). In this study, to map literature more accurately and systematically, co-word analysis is used.

Co-word analysis is a content analysis approach that utilizes patterns of co-occurrence of pairs of items (i.e., words or noun phrases) in a collection of texts to detect the links between concepts provided in these texts (Qin, 1999). The literature review in this study is divided into

four themes, and they are grouped according to the themes that emerged during co-word analysis. The theory behind the co-word analysis is that the co-occurrence of important terms represents the contents of the documents in a file (Callon et al., 1991). Themes are formed according to their Callon Density, which is a theme's progression and Callon Centrality, which is a measure of the theme's strength of the relationship with other themes, can also be called relevance to the literature (section 4.2.1.).

Four themes emerged during analysis; basic, motor, emerging or declining, and niche themes. Basic themes have high Callon Centrality and low Callon Density, meaning they lay the basis for the research field while having a low progression pace. "Project Management" and "Learning Systems" themes, which include papers not only restricted to the label, are the basic themes of the domain. Motor themes, having high Callon Density and Centrality, are well-developed and crucial for the field. "Construction" is the motor theme of the domain. Emerging or declining themes have both low Callon Density and Centrality, as they are poorly developed and peripheral to the field. "Management" is an emerging or declining theme, and the key point that determines whether a paper is emerging or declining is the keyword associated with the papers inside the cluster, including "design", "innovation management", "productivity", and "technology management. Niche themes, having low centrality and high density, are well-developed peripheral themes, indicating they are crucial for the field but peripheral to the field. "Optimization" and "algorithms" are the niche themes for the domain.

2.1. Literature Regarding Basic Themes

John McCarthy, the inventor of the term, defines Artificial Intelligence as the "science and engineering of making intelligent machines, especially intelligent computer programs" (McCarthy, 1985). Fridgeirsson aims to find how these intelligent computer programs will enhance the project management discipline for each of the 10 categories of project management knowledge domains specified by PMBOK in his article (which are Project Integration Management, Project Scope Management, Project Schedule Management, Project Cost Management, Project Quality Management, Project Resource Management, Project Communication Management, Project Risk Management, Project Procurement Management, Project Stakeholder Management) (Fridgeirsson et al., 2021). He claimed that AI will be an integrated phase of future project management practice and will have an effect on PMBOK

knowledge areas in the close future. He pointed out that, AI systems can help project managers estimate costs, manage schedules, track progress, provide reminders and follow-ups, manage tasks, and allocate resources and this will have a significant positive impact on cost, scheduling, and risk management. On the other hand, in knowledge domains and procedures that need human leadership abilities, such as team development, administration and stakeholder management, it is stated AI might have less influence.

Since the late 1970s, a lot of work had invested into systems that are collectively referred to as "decision support systems" (DSS) to give the manager/decision maker precise information regarding challenges faced. These systems frequently take the form of models, which may help analyze potential substitutes for the proposed solutions. Many businesses' decision support systems now include a variety of tools that were created to address somewhat structured situations. These tools are especially helpful for project management (Williams, Gary A., Boyd, William L., Boznak, Rudy, Phipps, 1990). The definition of Decision Support Systems is “systems that support cognitive processes of individual decision-makers via making computers useful by enabling the use of skilled intermediates, responsive service, and humanized software interfaces” (McCosh & Morton, 1980). There are various decision support systems offered in the literature, to maximize efficiency. One of the tools for reviewing efficiency is the Program Evaluation and Review Technique (PERT) which is a statistical method for evaluating and reviewing projects developed by Donald G. Malcolm (Malcolm et al., 1959). Another tool is the Critical Path Method (CPM), which is introduced by James E. Kelley and Morgan R. Walker (Kelley & Walkerf, 1959). After CPM and PERT were introduced, they dominated the project scheduling system and there was no better alternative project scheduling system with calibrated and proven distributions that don't require complicated user input for the era. Modern project management decision support systems (DSS) are more complex and extensive than PERT/CPM. Nonetheless, they make inadequate progress in terms of stochastic analysis. Hence in their paper, Trietsch & Baker examines the new PERT engine (PERT 21) and assesses it to check if it fits the 21st century or not (Trietsch & Baker, 2012). They claim that PERT 21 provides a radical new approach to project stochastic analysis, based on relevant and established theory. It operates in a complex but user-friendly manner. PERT 21 is meant to complement the current DSS, so it may be adopted without jeopardizing previous project management system investments.

AI in project management strives to ease and increase the effectiveness of project operations, as seen by a variety of applications. Its uses and approaches, which are usually

helpful, ranged from sophistication to risk management, estimating, strategic planning, Key Performance Indicator (KPI), forecasting, and experiment. Ong & Uddin discussed and revealed the existing status of data science and AI for the PM domain in their paper (Ong & Uddin, 2020). The potential future implementations and functionalities are identified, multiple patterns are detected, and the aggregate data are combined to present an accurate picture of Project Management's potential landscape. It is suggested that advanced implementations of AI will aid the simplification of present industry-standard practices. Several data scientist positions will surely emerge, particularly during the technological development process. As more conventional tasks are performed by technology, the higher-level positions will inevitably overtake them.

Another study that examines the effect of AI on PM is conducted by Garcia et al., which examines the advancements and problems in project control throughout the last several decades using computational intelligence methodologies, schools, and technology tools for project control, as well as open-source software for the use of Computational Intelligence (CI) approaches (García et al., 2017). Garcia claimed that project control is a difficult endeavor that entails a lot of ambiguity in terms of concepts and information, which is where CI methods prove helpful. He suggests the use of machine learning technologies in CI approaches for project assessment improves an organization's agility in the face of shifting leadership approaches brought on by the maturity gained via continuous development. The information presented in the article can help project-oriented companies make better decisions. In another paper, developing and using the Situation-Action Model for Human and Robot (AI) Resource Management, Tunc shared his thoughts and explanations on how AI and humans interact in the work environment and its effects (Medeni, 2018).

In his paper, Jüngen offers a broad foundation for creating complex systems for activities such as project management, dynamic scheduling, and design (Jüngen & Kowalczyk, 1995). The concept is built on the idea of addressing meta-constraint fulfillment issues dynamically, and it incorporates a variety of AI concepts that integrates a sophisticated backtracking mechanism into a completely automated system that creates solutions without the user's intervention. Because the approach has a clear logical foundation, it is possible to combine systems based on it with knowledge-based systems.

Kumar & Sarma aims to create an Intelligent Decision Support System (IDSS) that aids in project planning and scheduling in their article (Deepak Kumar & Sarma, 1996). An

Intelligent Decision Support System (IDSS) and the Project Influence Graph, which is a new project scheduling tool used by the IDSS are offered in the study. These tools assist the manager in making decisions and drafting a reasonable schedule of operations while considering resource and time limits, aiming to have a significant influence on the project's efficient administration.

Although AI has a lot to offer to the domain, there are certain necessities for project managers to fully utilize it. Niederman analyzed the domain to find out how AI contributes and get contributions to project management techniques (Niederman, 2021). He suggests that ordinary project managers are not likely to produce AI/analytics themselves, thus they do not need to master the technicalities of machine learning, hence software producers can offer PMs that as a product. In another study, Hazir examines project control system challenges, methodologies, and analytical models, as well as future research expansions examined within the literature in Earned Value Analysis (EVA) optimization techniques, and the architecture of decision support systems (DSS) to see how they may help project managers plan and control in unpredictable project contexts (Hazir, 2015). He pointed out the need to build analytical models to estimate project performance more precisely, particularly research on forecasting performance using new complete EVA measures and statistical control tools. The difficulties of supervising a complicated project due to a large number of performance indicators are discussed by Lauras. He aimed to provide project managers with more control over their projects' performance. According to Lauras, the published literature demonstrates that there is no defined instrument to support a global study of methodologies and tools for analyzing project performance according to various dimensions (cost, time, quality, risk, and so on). In his paper, he presented a multi-criteria method based on a performance cube with three dimensions: project activities or duties, performance indicator categories, and a summary of the performance trio (Lauras et al., 2010).

There are several tools offered for project managers to handle projects better in literature as follows;

Marques et al focus on decision support in service and product development initiatives and present a new multi-dimensional Project Performance Measurement System (PPMS) to help project managers handle large amounts of data (Marques et al., 2011). PPMS incorporates the unique characteristics of each project (tasks, priorities, decision-makers' personalities and

expertise), as well as several best practices in terms of global project management aspects and performance assessment.

On the other hand, non-technical issues are equally important for the project's sake. Forsythe & Buchanan suggests that nontechnical issues might go unnoticed by technical persons and these blunders and errors may ruin a project just as easily as technical ones might (Forsythe & Buchanan, 1992). It is claimed that managers and scientists, particularly knowledge engineers, are more prone to concentrate on technical problems with technological answers. Nontechnical concerns, on the other hand, are equally important and might be just as troublesome as technical ones. In conclusion, it is found that traditional thinking regarding developing expert systems oversimplifies the process by neglecting concerns that go beyond the machine-readable representation of an expert's knowledge. Knowledge engineering research implies that expert system project managers should focus further than popular belief says. Nontechnical factors, especially, are just as important as technical factors in the performance of a knowledge-based systems project.

Carroll investigates a project office that designed and deployed a structured, comprehensive Project Authorization Request tool. He suggests that the availability of a Project Authorization Request tool may considerably help in the training and development of the project and organizational employees, as well as serve as a key source of knowledge exchange (Carroll, 2004).

From delay to cash flow prediction and project duration, AI contributed to project management literature by providing project managers with superior computing power and reducing the dependency on human input.

Cheng & Roy suggest that AI can lessen dependency on human input in cash flow prediction systems (Cheng & Roy, 2011). They propose Evolutionary Fuzzy Support Vector Machine Inference Model for Time Series Data, which is a hybrid AI system to help with a proactive method to project performance management that focuses on cash flow forecasting.

Trappey aims to create an intelligent workflow management system that can manage complicated project processes, govern project processes, and dynamically distribute available resources for project implementation across company constraints (Trappey et al., 2006). In the research, a virtual web-enabled environment is used to intelligently reason and control processes as well as resource allocations using an expert system inference engine. The proposed

system makes it possible to accurately manage project outcomes, to satisfy the project's objectives and deliverables.

Wauters & Vanhoucke discusses five AI approaches for predicting project duration using Monte Carlo simulation, Principal Component Analysis, and cross-validation as an approach (Wauters & Vanhoucke, 2016). They proved that, when the training and test sets are at least similar, the AI approaches outperform the Earned Value Management (EVM) / Earned Schedule (ES) methods. Furthermore, the AI approaches produce outstanding predicting outcomes at the early and mid stages. A robustness experiment steadily widens the gap between the training and test sets, revealing the limits of the recently suggested AI approaches.

2.2. Literature Regarding Motor Themes

Artificial Intelligence, which is a cross-cutting theme as is widely observed in basic theme papers, is the motor theme, which means a well-developed theme that is crucial for the literature along with construction management. In this section, novel techniques provided by AI and approaches toward AI in various sectors, including construction management, are reviewed.

With the introduction of AI to business and management, there is increased emphasis on the individual, organizational, and social dimensions of AI, as well as systematic advances in primary studies such as more precision in assessment techniques thanks to the use of hybrid approaches (AI and non-AI) in problem-solving, and a holistic approach to AI design and evaluation. Cubric presented an analysis of current systematic reviews in this field of study and synthesized results relevant to AI adoption in business and management, including drivers, impediments, and societal consequences (Cubric, 2020a). In addition, the importance of the Intelligent Decision Support System is highlighted by Sarma. He examined complex decision-making from the perspective of intelligent decision-support systems and their uses in project management (Sarma, 1994). Sarma claims that the application of AI approaches assists people in making informed choices and training them in the meantime.

In terms of innovation, Botha examines the potential future development of innovation from a human-only approach to human-machine co-innovation and autonomous machine invention, as well as the benefits of potential autonomous machine innovation (Botha, 2019). Botha claims that, If these technologies are coupled with specialized creative support systems, they can offer great outcomes for people's behavior and even huge events. Humans as creative agents are anticipated to give way to human-machine co-innovation and, ultimately,

autonomous machine invention in the progress of machine innovation. Botha predicts that, in the future, all three innovation unit possibilities will emerge.

AI-based project management aims to solve the flaws of traditional approaches, which can be subjective depending on the circumstances. In one of the early studies, Milind Tambe and his colleagues described some of the key lessons learned from a group of personal assistant agents (Electric Elves) who were developed and implemented in a workplace (Tambe et al., 2008). For entities deployed in workspaces, the Electric Elves research resulted in numerous key insights concerning privacy and social norms. When such a system is introduced, a loss of privacy occurs in different instances and no systematic solution could be found for it. Another finding is that any agent, whether it is artificial or not, must follow the social norms of human society for that society to function properly.

In terms of risk management, Li & Mo aim to apply AI theory to determine the objective weight of risk indicators and perform a risk assessment to offer early risk warnings (Z. Li & Mo, 2020a). The objective weight of risk indicators is calculated using AI methodology in this study and the computed weight results are usually more accurate with AI, while the decision judgment on the evaluation factors is improved simultaneously. It aids decision-making by providing early detection of intellectual property issues via empirical analysis. Another study on the subject is conducted by Naz et al., which analyzed the importance of AI in developing a resilient and sustainable supply chain, as well as proposing the best options for reducing supply chain risk (Naz et al., 2021). Naz claimed that organizations and executives will be able to control rapid interruptions induced by any viral epidemic and quickly restore the supply chain if AI approaches are implemented. Technological advancements and AI applications will aid in the development of a robust supply chain, as well as risk mitigation, vendor selection, decision models, management information systems, network design, and information and optimization algorithms.

Brock & von Wangenheim provides a methodology for using AI successfully in the scope of digital transformation, suggesting that AI is identical to previous techniques that businesses adopt and utilize in many respects. (Brock & von Wangenheim, 2019) It is almost always used in digital transformation initiatives, and as a result, it has a lot in common with other initiatives. Hence, they reviewed the literature, conducted surveys and created a framework for effectively deploying AI in the context of digital transformation, including

advice that is gathered together under DIGITAL (Data, Intelligence, being Grounded, Integrated, Teamwork, Agility, and Leadership) guideline.

Another study on standardization by Pitt et al. examines the Cooperation Services Framework for standardizing the information flow across firms, creating project-wide standards, and determining access to and supply of project services, which is based on standardizing interactions by defining messages and protocols for inter-agent communication and collaboration amongst autonomous software agents (AI) (Pitt et al., 1996). Pitt proved how standardized project services could be offered using agreed-upon protocol specifications and a common representation of domain knowledge. The study also shows how inter-organizational contractual relationships can acknowledge local business conditions by allowing for every reviewer's agent to be designed in different ways, such as how a negotiated agreement is achieved, how a review is carried locally, domain, agent, and corporate expertise.

2.3. Literature Regarding Emerging or Declining Themes

In this section, literature regarding themes that are either emerging or declining themes is reviewed. Themes that have both low centrality and density are labeled as emerging or declining. The reason that both of these themes are in the same label is that emerging and declining themes have the same characteristic in terms of centrality and density. However, with thematic evolution analysis, they are differentiated in this study.

2.3.1. Literature Regarding Emerging Themes

Studies show that conventional project management theories cannot manage complex non-linear systems and Software development projects. Mitrovic et al. investigate the use of nonlinear functional correlations between important success criteria and project success to construct project-outcome prediction models utilizing systems thinking and artificial neural networks to gain insight into sophistication in software-project behavior (Mitrovic et al., 2020). According to Mitrovic, Software development projects are open networks of interconnected Critical Success Factors (CSFs) thus project management in software projects needs an AI-augmented approach. Critical Success Factors is a term introduced by D. Ronald Daniel, which is a management concept denoting a component required for an organization or project to

accomplish its goals (Daniel, 1961). Another article on the issue by Constantino presents a novel technique for managers to use while evaluating projects throughout the selection process (Costantino et al., 2015). The concept, development, and testing stages of a decision support system for project performance prediction are described in this work. According to Constantino et. al., the creation, validation, and testing of an artificial neural network model inherently link CSFs to project success. The model serves as a decision support system for project selection, showing early symptoms of failure by considering a project's compatibility with company strategy as well as the risk of project adoption.

The findings of ensemble models developed for estimating labor and time at the start of a project's lifetime show that they are quite precise when compared to other techniques used by different researchers and are acceptable for use. Pospieszny and his colleagues aim to close the gap between current study findings and implementation in the field of software estimation by utilizing machine learning algorithms, to overcome the shortcomings of conventional and parametric estimation methodologies, increase project success rates, and align with current development and project management practices (Pospieszny et al., 2018). Because a widely varied International Software Benchmarking Standards Group dataset of software projects from multiple organizations was used in this study in the learning process of Machine Learning (ML) algorithms, the predictive performance of models is higher with homogenous data particular to the chosen organization in which they will be implemented.

The complexity of risk analysis and planning makes it impossible to manage risks effectively by subjective judgment. Hu and his colleagues offer an Integrative Framework for Intelligent Software Project Risk Planning to aid in the reduction of project risks and the achievement of a more predictable project outcome (Hu et al., 2013). Hu suggests an Integrative Framework for planning purposes and is considered first in the domain, being the first empirical integrated intelligent model for risk analysis and planning in the Software Programming Risk Management sector.

2.3.2. Literature Regarding Declining Themes

The influence of digitalization on the rate of failure of Information Technologies (IT) projects is examined in “Proposal of a framework and integration of artificial intelligence to

succeed IT project planning" based on research conducted by multinational organizations. The data is analyzed with observational data in the domain of IT projects to discover difficulties and hazards associated with IT project management (Hassani & El Bouzekri El Idrissi, 2019). Finally, a technique is suggested by Hassani & El Bouzekri El Idrissi that allows AI to be integrated into IT project management. The suggested technique entails the creation of a platform that is deployed as software, which connects with a knowledge base created by previous IT projects to take advantage of feedback, provide the most appropriate planning for the project to be performed, and ensure the latter's fluidity of follow-up, as well as improved risk management. The proposed platform incorporates an expert system into the AI framework.

2.4. Literature regarding Niche Themes

The project management time estimation problem is a critical issue for project-oriented companies. Hajiali provides a model for project completion time estimation based on ensemble learning and specific project parameters in earn value management (Hajiali et al., 2020). The model provided by Hajiali proposes a generic, reliable, and resilient solution to tackle the estimating problem based on the dynamic nature of the projects. Another paper on the issue by Liu & Hao aims to detect difficulties in project management by incorporating successor prediction and renewable resource aspects (Liu & Hao, 2021). They use the forecasting models "Long Short Term Memory" (LSTM) and "gated recurrent unit" to provide innovative approaches in this study. The presented models in the study provide reliability and resilience in project schedule prediction.

The Nearest Neighbour approach was introduced to enhance project control forecasting by Wauters & Vanhoucke. In their study, a Nearest Neighbor-based extension for project control forecasting with EVM is utilized for two objectives. First, the k-Nearest Neighbour technique was used as a predictor, and its precision and consistency were compared to those of current EVM and AI approaches. Secondly, by decreasing the training set to a smaller training set with more comparable findings, Nearest Neighbours were used to interbreed the AI approaches (Wauters & Vanhoucke, 2017).

Artificial Intelligence has a significant impact on procurement management. Buyers can use AI to tackle complicated issues that were formerly unsolvable or to which they had previously discovered ineffective solutions. In his study, Allal-Cherif investigates how AI may help procurement management operate better. He stated that intelligent information systems

assess the environment and give information that aids buyers' decision-making, and afterward assess their suggested solutions, create scenarios, and proposes which will deliver the greatest performance and the least risk. AI stretches the boundaries of what customers can do in terms of new objectives (Allal-Chérif et al., 2021).

Chou analyzed the performance of several classification methods in project dispute resolution in his study, by using a mix of fuzzy logic, a fast genetic algorithm, and Support Vector Machines (SVMs) (Chou et al., 2013). He claims that, although the hybrid model is more complicated and time-consuming than other systems, a proper combination of AI could greatly increase classification testing performance.

Project managers can monitor cash flow patterns as well as effectiveness before planned Expend Cash Flow execution using the AI methodologies. In his paper, Cheng employs AI techniques to forecast cash flow patterns for construction projects attempting to generate proper approaches based on the float, process execution time, construction rate, and resource demand. The method that Cheng and his colleagues offer project managers a lot of help with cash flow management and developing relevant solutions promptly (Cheng et al., 2009).

3. DATA MANAGEMENT

Over the past 15 years, Web of Science (Birkle et al., 2020), Scopus and Google Scholar have been the three most prominent interdisciplinary bibliographic data sources, which provide metadata about scientific papers as well as citation linkages across them (Visser et al., 2021). Since the Google Scholar database lacks most of the features needed for an exhaustive bibliometric analysis, it had been ruled out. Web of Science and Scopus databases had been utilized for this research. A search on databases was conducted on 25 January 2022.

3.1. Search Strategy

"Project Management" and "Artificial Intelligence" keywords are used for search, and the database is restricted to WoS and Scopus indexed articles. As the structure of each data source differs, some minor alterations had been done during the search to refine the results as follows;

Web of Science: In the search within WoS, "Project Management" and "Artificial Intelligence" keywords are used, and the search is conducted through the "topic" function, which searches terms through the title, abstract, and author keywords. Documents are refined by type, including only Articles or Review Articles. In addition, documents are also refined by index, only Social Sciences Citation Indexed (SSCI) articles are selected for the study. 115 articles are returned from the query from WoS[1] at the time this study was conducted. The records are defined as "Full Record and Cited References". Results are exported as ".bib" files.

Scopus: In the search within Scopus indexed articles, "Project Management" and "Artificial Intelligence" keywords are limited to exact keywords with Boolean operators. 395 articles from Scopus[2] are returned from the query at the time this study has been conducted. Searches are conducted with an advanced search option with Boolean operators within the "search within article title, abstract, keywords" option, which searches the input through title,

[1] Web of Science query link: https://www.webofscience.com/wos/woscc/summary/0fe72e38-4141-4acf-9ad6-d549b845d8c3-02596bcf/relevance/1

[2] Scopus query link: https://www.scopus.com/results/results.uri?sort=r-f&src=s&nlo=&nlr=&nls=&sid=9e69a87ded90a4bd19fd3d7952577f36&sot=b&sdt=cl&cluster=scoexactkeywords%2c%22Project+Management%22%2ct%2c%22Artificial+Intelligence%22%2ct%2bscosubtype%2c%22ar%22%2ct&sl=65&s=TITLE-ABS-KEY%28%22project+management%22+AND+%22artificial+intelligence%22%29&origin=resultslist&zone=leftSideBar&editSaveSearch=&txGid=fef1c808dbe3e7ca00829e84ce387818

abstract, and keywords. Documents are refined by type, including only Articles. Results are exported as ".bib" files.

3.2. Data Merging & Data Cleaning

When bibliometric analysts analyze the Scopus and the WOS databases, they usually do two separate analyses: one on the Scopus collection and another on the WOS domain. However, in this study, both databases are merged, since a bibliometric study that uses data from Scopus or WOS individually cannot provide a complete view of a field's knowledge and trends, as proven by a recent study by Echchakoui (Echchakoui, 2020). In this study, the Institute for Scientific Information (ISI) Web of Science (WoS) and Scopus databases are merged and used for Literature Review on the topic "Artificial Intelligence in Project Management".

Data cleaning is the process of finding and fixing mistakes in the database. As data is gathered and combined from numerous sources into a database, guaranteeing good data quality and consistency becomes a substantial, frequently demanding, and always difficult undertaking. Any analysis of the data is not useful without accurate and clean data (Deshmukh & Wangikar, 2011). Data merging and Data Cleaning in this study have been done in 3 steps.

3.2.1. Dataset Importing

Dataset importing in this study has been done via the bibliometrix R package. The bibliometrix R package [3] contains a suite of utilities for quantitative bibliometric and scientometric studies. It's written in R, an open-source programming language and ecosystem. The availability of robust, effective statistical algorithms, access to high-quality numerical routines, and integrated data visualization capabilities are possibly the most compelling reasons to choose R over other languages for scientific computation (Aria & Cuccurullo, 2017).

The convergence procedure from the ".bib" format to ".xlsx" is done via the biblioshiny app, offering features of the bibliometrix library with a graphical interface. It aims to assist academics in reaching most of bibliometrix's core elements. Within the biblioshiny app, the following procedure has been followed;

[3] http://www.bibliometrix.org

“Select Import raw file(s) -> Import the.bib file -> Select Save as Excel”

Following this, the databases are named “WoS” and “Scopus”. The naming is important since it will be used later in the R-Studio as defined in the study.

3.2.2. Data Cleaning

Data cleaning in this study has been done in two steps. First, importing raw files to biblioshiny applies a two-step data cleaning as an initial step. It translates all characters into capital letters and puts semicolons to separate different items in the same column. This procedure prevents bibliometrix to interpret the same author or reference with different representations as different units. The second step is the removal of the duplicate entries, which is conducted simultaneously at the merging step. Bibliometrix uses the function “convert2df” to identify and removes duplicate records.

Table 3.1: WOS field tag (Web of Science Core Collection Help, 2018)

Field Tag	Description
AU	Authors
TI	Document Title
SO	Publication Name (or Source)
JI	ISO Source Abbreviation
DT	Document Type
DE	Authors’ Keywords
ID	Keywords associated by SCOPUS or ISI database
AB	Abstract
C1	Author Address
RP	Reprint Address
CR	Cited References
TC	Times Cited
PY	Year
SC	Subject Category
UT	Unique Article Identifier
DB	Bibliographic Database

In biblioshiny, The Clarivate Analytics WoS Field Tag codify is used to label the columns in the data frame, as can be seen in Table 3.1 (Web of Science Core Collection Help, 2018). This labeling enables to merging of different representations under the same dataset.

3.2.3. Data Merging

Dataset Merging in this study is done via bibliometrix and the merging is conducted using the following code:

```
library(bibliometrix)
library(xlsx)
combined<-mergeDbSources (WoS, Scopus, remove.duplicated = T)
```

The combination function within the code also removes duplicates, and 14 duplicate documents had been removed during the process.

As a final step, the ID section, which includes Keywords Plus is merged with the DE section, which is Author's Keywords to supply keywords to articles without Keywords Plus. Keywords Plus is a feature provided by the Institute for Scientific Information (ISI) database. After every new source article is processed in ISI (with an average of 20 cited references), an algorithm searches the primary source file for the titles of all cited papers—that is, all articles processed by ISI in the past 20 years. The best candidate keywords are selected and ranked using various algorithms based on the title words and phrases and labeled as Keywords Plus (Garfield, 1990).

4. METHODOLOGY, ANALYTICAL FRAMEWORK AND ANALYSIS

"The pattern of bibliographic references indicates the nature of the scientific research front" (De Solla Price, 1965). As quoted by Price, bibliographic patterns in a research area demonstrate the nature, history, and possible evolution path of the domain. To conduct bibliometric analysis, Price utilized network theory and examined a network of scientific papers.

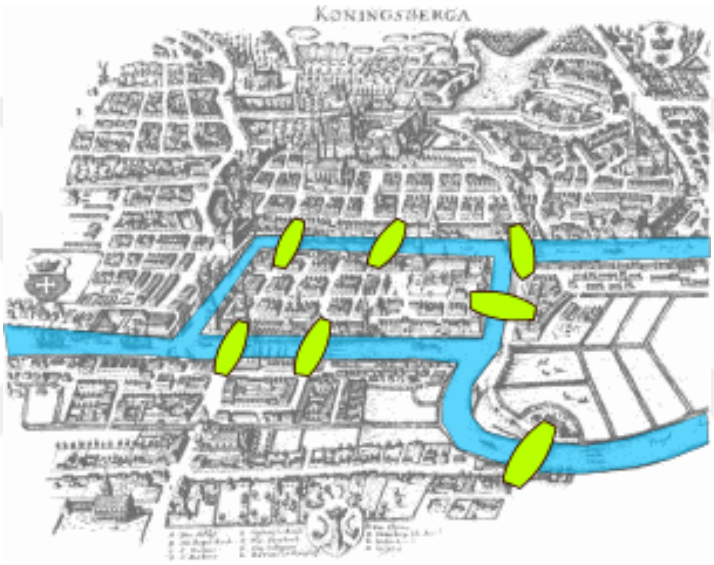


Figure 4.1. The problem of the seven bridges of Königsberg (Giuşcă, 2005).

Origins of network theory track back to the graph theory. The solution of Leonard Eulers to the Königsberg bridge problem, "Solutio problematis ad geometriam situs pertinentis" (Euler, 1741) created the foundation of the graph theory, which provides a basis for network theory. Rather than the solution, the methodology for it was inspirational as a concept, since Euler modeled the Konigsberg problem, which to make a trip across the city that would only pass each of those bridges once, which can be seen in Figure 4.1 (Giuşcă, 2005). Euler solved the problem in a fashion that considers areas divided by bridges as a graph, a collection of nodes connected by links. He proved that such a trip is impossible, which is an implication coming along with this solution is that, graphs (or networks) have properties that restrict or expand our abilities to do things with them, which are concealed in their creation.

Following Euler's contribution, Paul Erdös and Alfred Renyi, with their 8 articles on the subject[4] listed in Karonski's article (Karoński & Ruciński, 2013), contributed to graph theory with the concept of random graph theory which is called Erdös – Renyi Model (Erdös & Rényi, 1959). According to Erdös and Renyi, after certain connections, every node in the graph will have at least one link and a giant cluster emerges after a certain point. Any information will be passed through every node. As links increases, the chance that a node left separated decreases. From the social network perspective, every node mentioned is a person and the giant cluster is society itself. Erdös himself affected the bibliometric analysis domain, having his coefficient of collaboration, which is named "Erdös number", scientific distance from one author to Erdös, an academic distance of authorship. Examples show that the scientific world is tightly connected since various scientific papers from different disciplines have an Erdös number less than 5.

A significant contribution, with a different perspective, is given to the subject by Mark Granovetter in his paper, by connecting micro and macro levels of sociological theory via analyzing social networks. In the paper, Granovetter runs an experiment, trying to explain and conceptualize the mechanic behind finding a job. He finds out that, people tend to find jobs through acquaintances rather than close friends. From this point of view, Granovetter imagines society differently than Erdös and Renyi, who are taking it as a random universe. He defines the strength of a tie as "a combination of the amount of time, the emotional intensity, the intimacy (mutual confiding), and the reciprocal services which characterize the tie" (Granovetter, 1973) and claims that society is a structure composed of small clusters which are complete graphs, connected by weak social ties. It implies that weak ties are a node's connection to society.

Clustering beyond the social network context is analyzed in the paper "Collective dynamics of 'small-world' networks" by Watts & Strogatz (Watts & Strogatz, 1998). To explain the clustered nature that we observe in real-life examples, Watts and Strogatz introduced a measurement technique called "clustering coefficient". In a friendship context, in which Strogatz introduced the term, a higher clustering coefficient means stronger ties between

[4] On random graphs I, Publ. Math. Debrecen 6 (1959), 290-297. On the evolution of random graphs, Publ. ~-1ath. Inst. Hung. Acad. Sci. 5 (1960), 17-6l. On the evolution of random graphs, Bull. Inst. Internat. Statist. 38, 343-347. On the strength of connectedness of a random graph, Acta :Math. Acad. Sci. Hungar. 12 (1961),261-267. Asymmetric graphs, Acta Math. Acad. Sci. Hung. 14, 295-315. On random matrices, Publ. Math. lnst. Hung. Acad. Sci. 8 (1964), 455-461. On the existence of a factor of degree one of a connected random graph, Acta Math. Acad. Sci. Hung. 17 (1966), 359-368. On random matrices II, Studia Sci. Math. Hung. 13 (1968), 459-464.

your friends' friendships. It is widely used in bibliometric analysis while conducting co-citation and co-word analysis.

Although the models above, in his book, Albert-László Barabási claimed the existence of hubs and connectors (nodes having a large number of links compared to the average) contradict the random universe models of Erdös-Renyi and Watts-Strogatz (Barabási, 2002). Barabási explained the phenomenon through Web pages, which follow a power law (Albert et al., 1999). Instead of the bell curve, which is normally observed in nature, in the Web-page case, the power-law is observed. Power law distribution doesn't have a maximum point; it is a continuously decreasing curve. It implies there is a high discrepancy amongst the population. According to the random network theory, there are random nodes that have characteristics representing the whole group within its attributes, however in power law distributed networks there is no such characteristic node, thus Barabasi and his fellows called the power-law distributed networks scale-free networks (Barabási, 2002). In terms of bibliometric analysis, Derek de Solla Price demonstrated that the number of a paper's citations has heavy-tailed distribution, which follows a Pareto distribution (power law). It indicates that the citation network is scale-free (De Solla Price, 1965).

Through the techniques that had been developed thanks to graph theory and network theory, bibliometric analysis as an analysis method emerged. A precise definition for bibliometric analysis is "an analysis method that is a common and thorough approach for discovering and evaluating vast volumes of scientific data, allowing examine the evolutionary nuances of a particular discipline while also offering insight on the field's developing aspects". The history of bibliometric analysis has roots in the early 20th century. The first quantitative analysis of literature is conducted by F. J. Cole and N. B. Eales in 1917 (Cole & Eales, 1917). Alan Pritchard coined the term bibliometric in his article as "the application of mathematics and statistical methods to books and other media of communication" (Pritchard, 1969).

Bibliometric analysis has been conducted in this study to conduct a comprehensive analysis of the domain and map its future. There are two types of bibliometric analysis techniques: performance analysis and science mapping. In summary, performance analysis considers the contributions of research parts, whereas science mapping considers the links among them (Donthu et al., 2021). In this study, both science mapping and bibliometric performance analysis are used as bibliometric analysis techniques.

4.1. Bibliometric Performance Analysis

According to Noyons, "Bibliometric performance analysis is evaluating groups of scientific actors based on bibliographic data" (Noyons et al., 1999). By conducting a performance analysis with various measures, a bibliometric analysis may be strengthened. These measures are classified into two types: quantitative and qualitative. While qualitative measures demonstrate the (supposed) performance depends on the bibliometric effect of such topics and thematic areas, quantitative measures examine the productivity of the identified themes and thematic areas (Cobo et al., 2011).

Performance analysis may be widely used in many reviews since it is common practice for reviews to report the performance of various research constituents (such as authors, organizations, nations, and publications) in the field. This approach is comparable to the context or participant profile that is generally offered in empirical research, albeit it is done more analytically (Donthu et al., 2021). The results of the performance analysis of this study are as follows;

Table 4.1: General information about data

DESCRIPTION	RESULTS
Timespan	1987-2022
Sources (Journals, Books, etc)	275
Documents	494
References	21564

Source: author's own work

As can be seen from Table 4.1, the data in this study covers articles from 1987 to 2022. There are 494 different documents from 275 different sources. There are 21,564 references in total subject to the bibliometric analysis.

4.1.1. Publication Related Metrics

Publication related metrics cover a wide range of research activities, and some of them may be used to show not just how productive a researcher is but also how influential or impactful his or her published papers are. Numerous academic and scientific institutions have discussed the value of quantitative studies of publication-related metrics in discovering traits,

trends, and linkages that may be used to indicate productivity or influence (Carpenter et al., 2014). In the study, the following metrics are examined to analyze the domain;

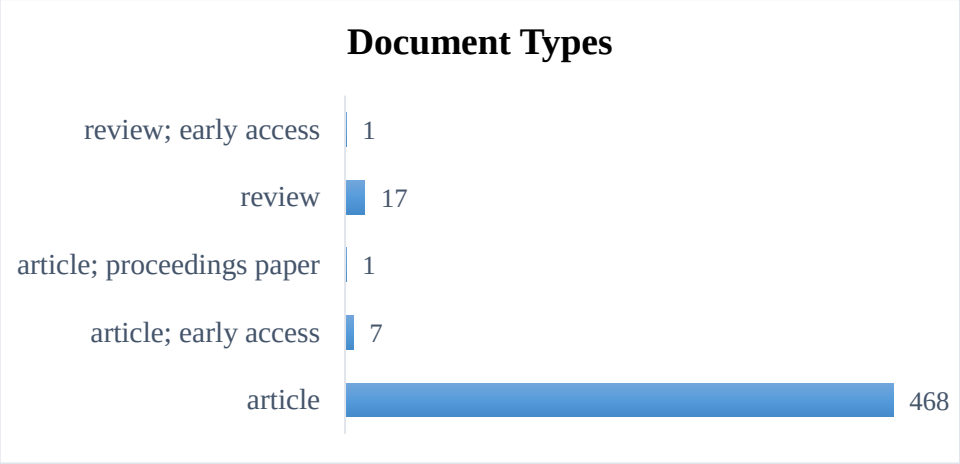


Figure 4.2: Document types (Source: author's own work)

Figure 4.2 demonstrates that, out of 494 documents, 1 of them is an early access review and 1 of them is a proceeding paper. There are 17 reviews, 7 early access articles, and 468 articles.

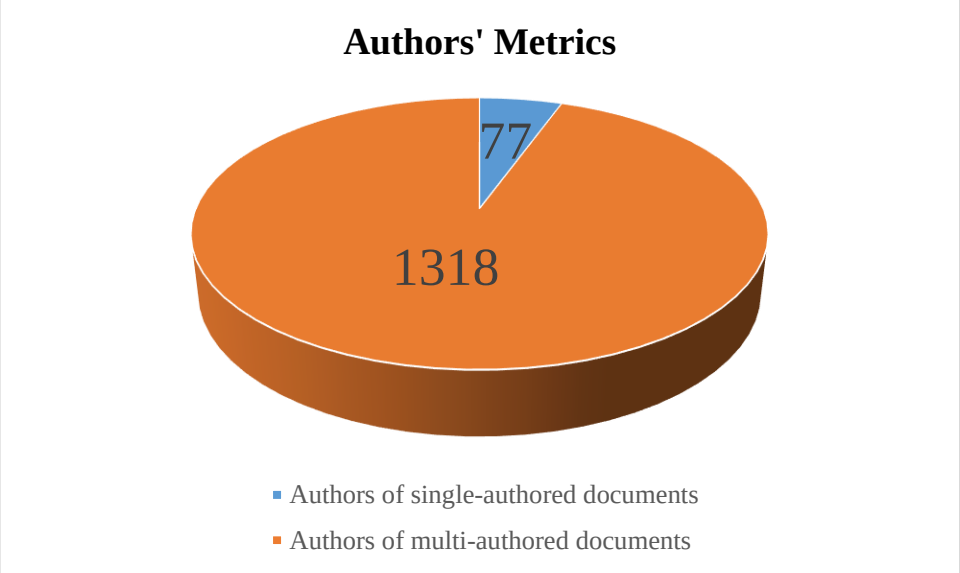


Figure 4.3: Authors' metrics (Source: author's own work)

Figure 4.3 represents the metrics about authors which is included in the bibliometric study. There are 1395 unique authors in total, 1318 of them are involved in multi-authored documents and 77 of them are involved in single-authored documents. There are 1557 total

author appearances in documents, considering the same author can contribute more than once in the dataset.

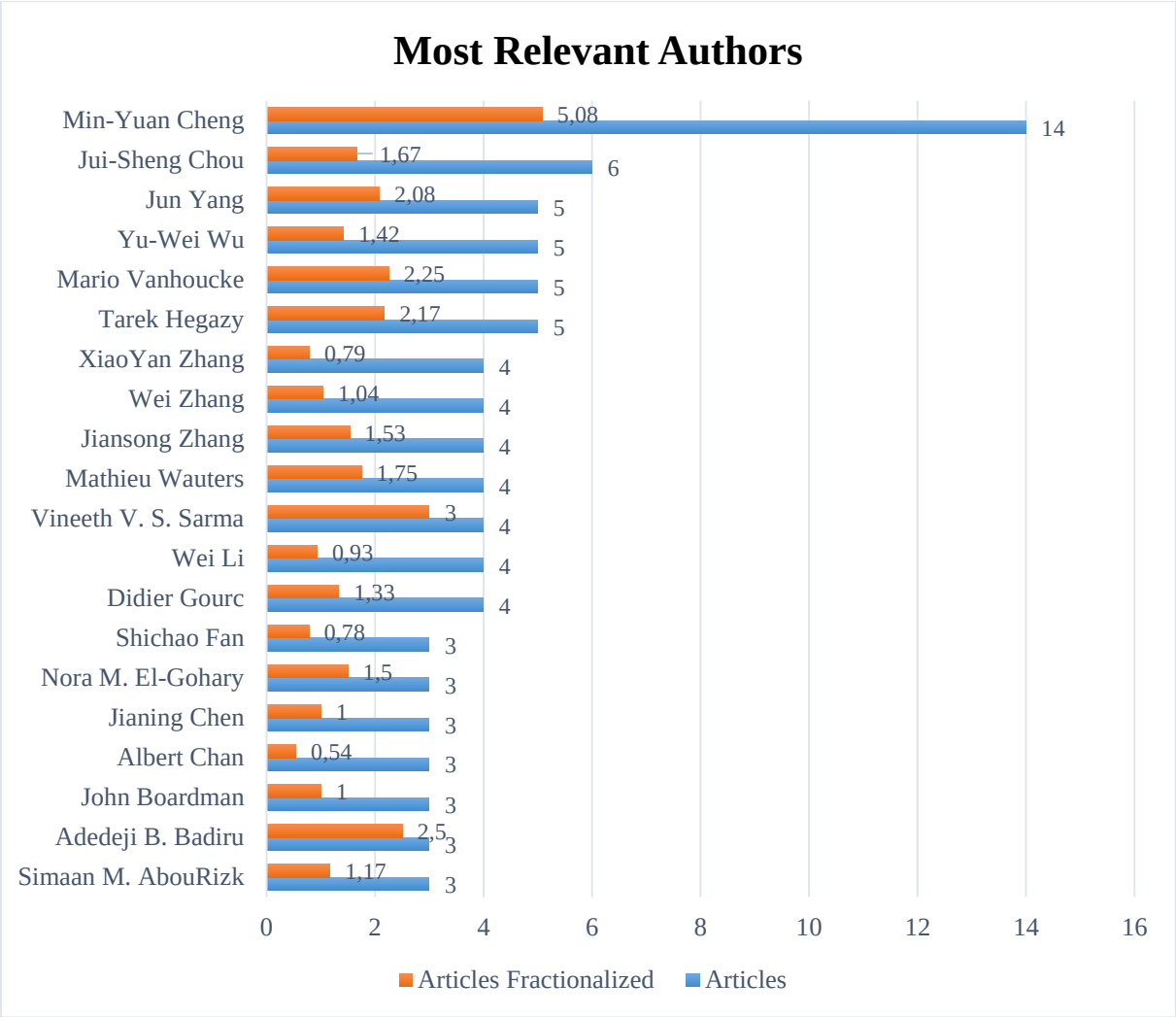


Figure 4.4: Most relevant authors (Source: author's own work)

In Figure 4.4, "Most Relevant Authors" is shown. The author with the most article (14 articles in total) is Professor Min-Yuan Cheng from the National Taiwan University of Science and Technology with 14 articles. His major field is Construction Management and he is interested in applications of artificial intelligence and Management Information Systems, which made him the most influential researcher in the domain. The second most popular researcher in the domain is Professor Jui-Sheng Chou, who is also from the National Taiwan University of Science and Technology Civil and Construction Engineering department like Professor Cheng. His domain is Project Management, Artificial Intelligence for Civil & Hydraulic Engineering Informatics, which makes him the second most popular researcher in the field with 6 articles on the subject. Professor Tarek Hegazi, author of the textbook "Computer-Based Construction

Project Management" is the third most popular researcher in the field. He teaches at the University of Waterloo's Civil Engineering Department. He contributed to the domain with 5 articles. The rest of the authors and their contributions can be seen in Table 4.2.

Table 4.2: Author article metrics

Author Full Name	**Affiliation**	**Articles**	**Articles Fractionalized**
Min-Yuan Cheng	China	14	5,08
Jui-Sheng Chou	China	6	1,67
Tarek Hegazy	USA	5	2,17
Mario Vanhoucke	Belgium	5	2,25
Yu-Wei Wu	China	5	1,42
Jun Yang	China	5	2,08
Didier Gourc	France	4	1,33
Wei Li	China	4	0,93
Vineeth V. S. Sarma	India	4	3,00
Mathieu Wauters	Belgium	4	1,75
Jiansong Zhang	USA	4	1,53
Wei Zhang	China	4	1,04
XiaoYan Zhang	China	4	0,79
Simaan M. AbouRizk	Canada	3	1,17
Adedeji B. Badiru	USA	3	2,50
John Boardman	England	3	1,00
Albert Chan	China	3	0,54
Jianing Chen	China	3	1,00
Nora M. El-Gohary	USA	3	1,50
Shichao Fan	China	3	0,78

(Source: author's own work)

Table 4.2. represents Author's name, affiliation, articles and articles fractionalized. Articles fractionalized measure the contributions of each author to the number of papers that have been published (Van Hooydonk, 1997). The formula for the fractionalized number of authored documents is as follows;

$Frac\ Freq\ (AU_j) = \sum_{h\ \in\ AU_j} \frac{1}{number\ of\ CoAuthors\ (h)}$ and AU_j is the number of papers co-authored by the author j and h is a paper included in AU_j.

Fractional authorship in research is a trending topic, as publishing pressure increases on researchers, co-authoring articles becomes a preferable choice rather than authoring a unique article. According to the study by Dr. Andrew Plume and Dr. Daphne Van Weijen, over the last ten years, the number of authorships per unique author has climbed but the number of publications per unique author has decreased (Plume & Weijen, 2014). This is also reflected in the table, while Min-Yuan Cheng, the top professor at the table who has been publishing since 1989 has a great margin between articles and articles fractionalized, while researchers who started publishing more recently, e.g. Vineeth V. S. Sarma who has been publishing since 2012, has a closer gap between their value of unique articles and the articles fractionalized.

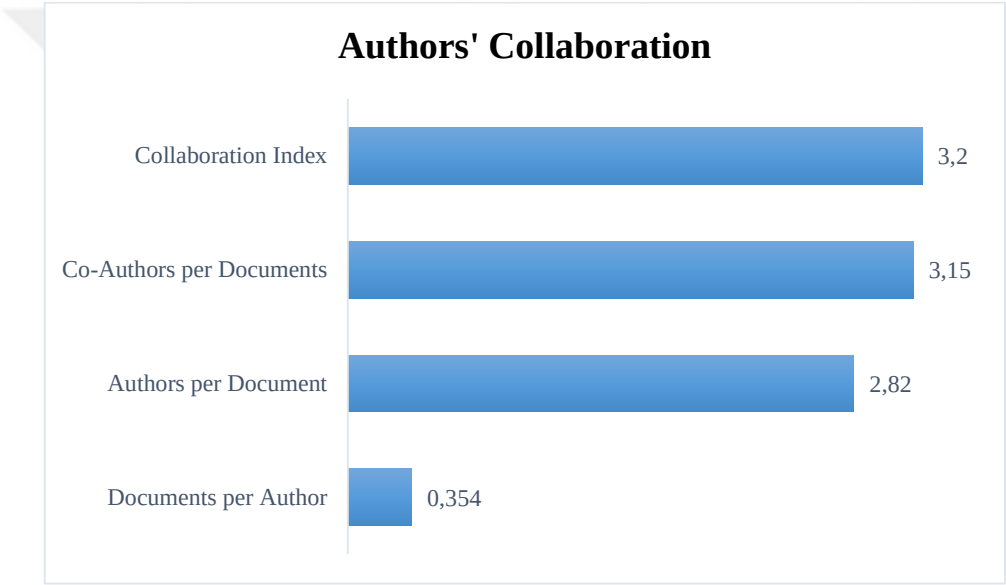


Figure 4.5: Authors' collaboration (Source: author's own work)

In Figure 4.5, the Authors' collaboration is depicted. The collaboration index for this dataset, which is the average number of authors for a collaborative paper is 3,2. Per document, there are 3,15 co-authors and 2,82 authors, and documents per author are 0,35 on average.

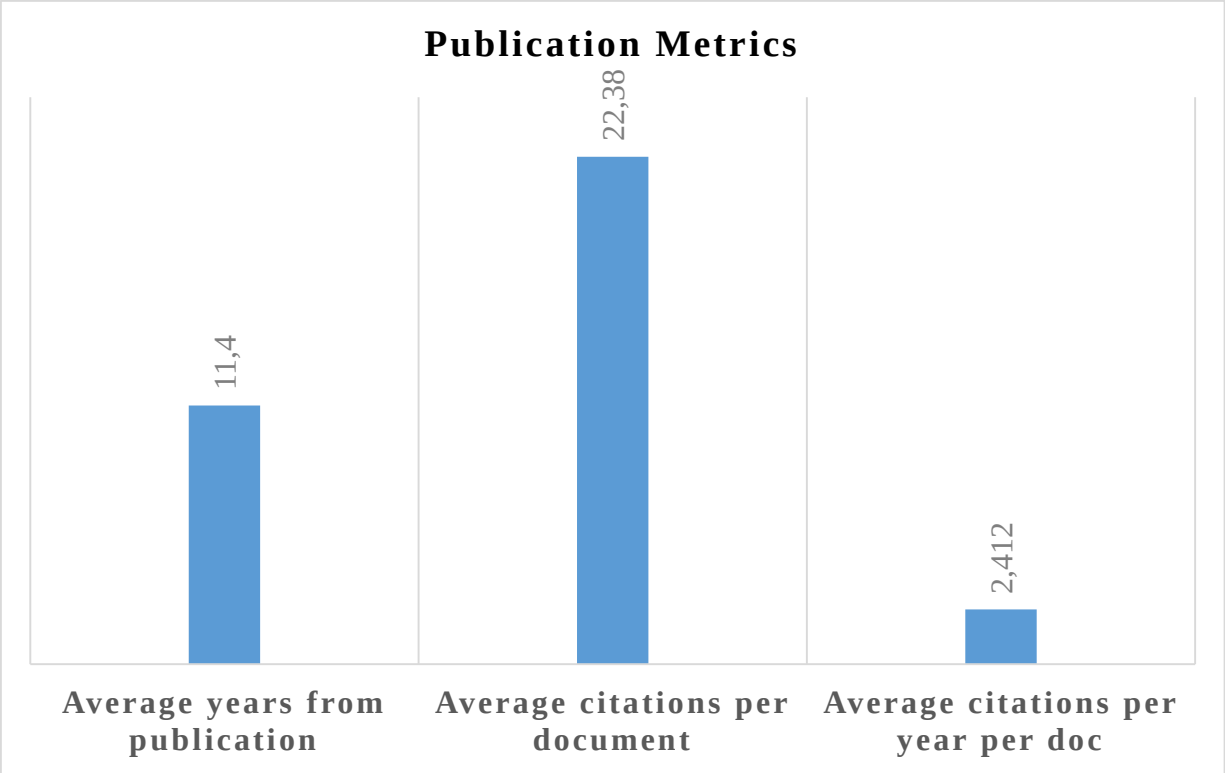


Figure 4.6: Publications metrics (Source: author's own work)

According to Figure 4.6, the average years from publication, in other words, average years to a publication to be cited is 11,4. While every document gets 2,412 citations per year on average, the average number of citations per document is 22,38 in total.

4.1.2. Citation Related Metrics

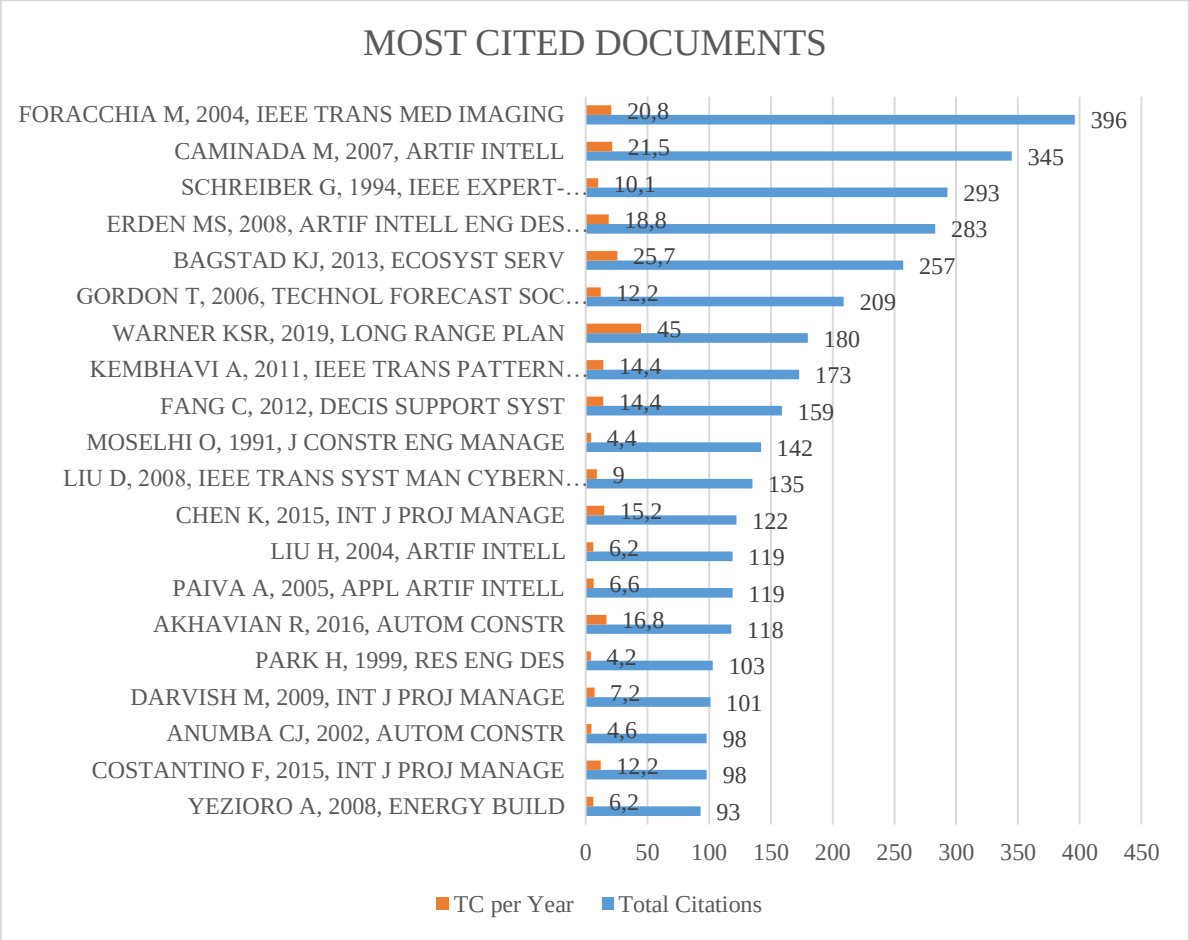


Figure 4.7: Most cited documents (Source: author's own work)

In Figure 4.7, the most globally cited documents had been depicted. Total Citations (TC) represents the number of times each document had been cited and TC per year represents the yearly average. The most global cited document of the domain is "Detection of Optic Disc in Retinal Images by Means of a Geometrical Model of Vessel Structure" by M. Foracchia, although being a medicine-related paper, it is a basic paper and an early example of usage of AI on an extensive dataset for intuition (Foracchia et al., 2004). The second most cited paper is "On the evaluation of argumentation formalisms" by Dr. Martin Caminada, a paper about argumentation theory, which is to build arguments for and against a statement, choose the "legitimate" ones, and eventually decide if the initial assertion may be accepted or not (Caminada & Amgoud, 2007). The third most cited paper is "CommonKADS: A Comprehensive Methodology for KBS Development by Schreiber et. Al. By building a set of engineering models with organizational structure and application-specific logic in mind, CommonKADS (Knowledge Acquisition Data System) aims to meet the demand for a

systematic approach for Knowledge-Based Systems (KBS) projects (Schreiber et al., 1994). Rest of the most cited documents can be seen at Figure 4.7.

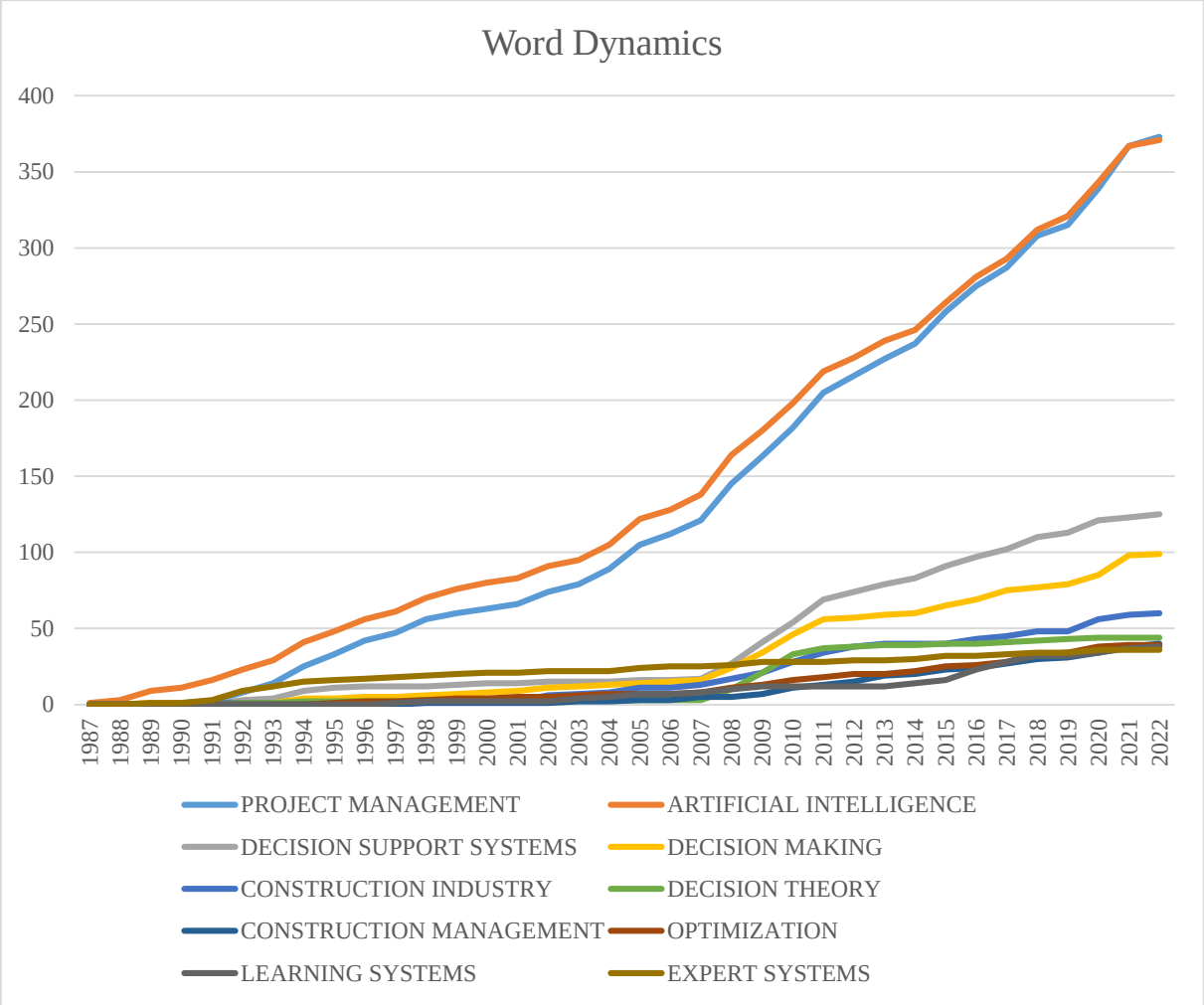


Figure 4.8: Word dynamics (Source: author's own work)

In Figure 4.8, word dynamics in the domain can be observed. The figure reflects total keyword occurrences from 1987 to 2022. Starting from 1987, "Project Management" and "Artificial Intelligence" is growing at a steady rate summing up more than 350 keyword occurrences in total. The third most popular keyword is Decision Support Systems, which emerged in 1993, and observed a sharp increase between 2007 to 2011 and then increased at a decreasing rate until 202, summing up to more than 100.

4.2. Network Analysis & Enrichment Techniques

Network analysis is a collection of complementary methodologies used to represent the relationships between actors and to examine the social structures that result from the repetition of these relationships. The underlying premise is that examining the relationships between things will produce better explanations of social processes.

The following indices and tools have complemented this study to enhance the results of the analytical techniques used in bibliometric research, based on the fundamental approaches of bibliometric analysis. In all, three network analysis-based enrichment pathways, network metrics, clustering, and visualization are used.

4.2.1. Network Metrics

Network metrics can be utilized to supplement bibliometric analysis evaluations. They give information on the relative relevance of research elements that aren't often represented in publications or citations (Donthu et al., 2021). The following metrics are used in this study to enrich bibliometric assessments;

4.2.1.1. Betweenness Centrality

Freeman coined the term betweenness centrality as "the degree to which a point falls on the shortest path between others and therefore has a potential for control of communication" (Freeman, 1977). He mentioned that it may be used to index centrality in any network of symmetrical relations. Betweenness centrality represents the position and the power of the node within the network, the information that goes through it makes it central and more important. The formula for betweenness centrality is

$$C_B(k) = \frac{1}{2}\sum_i \sum_j \frac{\sigma_{ij}(k)}{\sigma_{ij}} \quad where\ i \neq j \neq k$$

$$\sigma_{ij} = total\ \#\ of\ shortest\ paths\ connecting\ i\ and\ j$$

$$\sigma_{ij}(k) = total\ \#\ of\ shortest\ path\ goes\ through\ k$$

4.2.1.2. Closeness centrality

Closeness Centrality defines how proximal a node is to other nodes within the network. It is measured as the mean of the minimum path lengths from the node to every other node in the network. The formula for the closeness centrality is as follows:

$$Cc(N_i) = \frac{1}{\sum_{j=a}^{n} d(N_i, N_j)} \quad , \qquad where\ (i \neq j)$$

Where N represents the node and $d(N_i, N_j)$ represents the distance between node i and node j. (Beauchamp, 1965). It can be interpreted as the "capability to carry information effectively".

4.2.1.3. Equivalence Index

The equivalence index is a measure of the similarity of "n" keywords. The formula for the equivalence index is as follows:

$e_{nm} = \frac{c_{nm}^2}{c_n c_m}$ where,

c_{nm} represents the number of publications keywords n and m appearing both

c_n represents the number of publications including the keyword n

c_m represents the number of publications including the keyword m

4.2.1.4. Callon's (Cluster) Centrality

Callon's centrality measures the intensity of a cluster's links with other clusters. The greater and stronger these relationships are, the more this cluster indicates a subset of research topics that the scientific or technical community considers critical. Callons' Centrality "c" is calculated as

$c = 10\ x\ \sum e_{nm}$ where

"n" and "m" are keywords that belong to different themes

" e_{nm}" is the equivalence index between keywords n and m, which is a metric for comparing objects based on the frequency of keyword co-occurrences (Callon et al., 1991).

4.2.1.5. Callon's Density

Callon's density quantifies the internal strength of a group. This number might be interpreted as a measure of the theme's progression.

$d = 100 \times \sum \frac{e_{ij}}{\omega}$ where keywords "i" and "j" belong to the same theme,

ω represents the number of the keywords

e_{ij} represents the equivalence index between keywords "i" and "j"

4.2.1.6. PageRank score

Introduced by Google's founders Sergey Brin and Larry Page, "PageRank is a global ranking of all web pages, regardless of their content, based solely on their location in the Web's graph structure" (Page et al., 1998). PageRank score approximates the likelihood that any message will arrive at a specific vertex.

The formula for PageRank is as follows:

$$R(u) = c \sum_{v \in B_u} \frac{R(v)}{N_v}$$

u is a node (a web page in the original study)

F_u is the set of nodes u points to

B_u is the set of nodes that point to u.

Let $N_u = |F_U|$ is the number of links from u and

c is a factor used for normalization (so that the total rank of all nodes is constant).

PageRank score considers the direction of the links as well, hence it reflects if these bonds are one-way or bilateral.

4.2.1.7. Inclusion Index (II)

The Inclusion Index, also known as the Simpson coefficient, is a measure of overlapping used in feature extraction. The index is introduced by George G. Simpson in his article, "Notes on the Measurement of Faunal Resemblance" (Simpson, 1960). It calculates the amount of overlap across two sets. The measure is computed by dividing the intersection size by the smaller of the two set sizes.

The formula for the Inclusion Index is as follows;

$$overlap(X, Y) = \frac{|X \cap Y|}{\min(|X|, |Y|)}$$

If set X is a subset of set Y or vice versa, the overlap coefficient value is 1 (Vijaymeena & Kavitha, 2016).

4.2.1.8. Stability Index (SI)

The Stability Index is introduced by Henry G. Small, which is used to assess the continuity of clusters. The Stability Index is also used to assess the stability of individual items across two successive periods.

The formula for the Stability Index is as follows;

$$SI = \frac{\left|\bigcap_{i=1}^{N} C_i\right|}{\left|\bigcup_{i=1}^{N} C_i\right|}$$

4.2.1.9. Collaboration Index

The collaboration index is the average number of authors for a collaborative paper. The formula below was used to get the average number of authors for joint-authored papers (Elango & Rajendran, 2012).

$$CI = \frac{Total\ Authors\ of\ Collaborative\ Articles}{Total\ Collaborative\ Articles}$$

4.2.2. Clustering

The quantitative method of categorization is cluster analysis. It helps create decision rules, which are subsequently used to allocate a heterogeneous group of objects to several connected data subsets (clusters). Practically most of this technique is practical rather than theoretical. As a consequence of cluster analysis, classes are displayed graphically (Rousseaux & Gad, 2013).

4.2.2.1. Louvain Method

The Louvain method is a clustering method that identifies high modularity partitions of complex networks and unfolds a comprehensive hierarchical community structure for the network, allowing access to various community detection resolutions (Blondel et al., 2008). Louvain clustering method is used in the bibliographic coupling, co-citation analysis, co-word analysis, and thematic evolution analysis in this study.

4.2.2.2. Edge Betweenness (Girvan – Newman algorithm)

Girvan and Newman proposed a clustering method by expanding Freeman's betweenness centrality and describing an edge's betweenness as the quantity of shortest routes that cross among the adjacent set of vertices to determine which edges inside a network are greatest among those sets. Based on the theory, all path is considered equal such that the sum of the weights of all the pathways equals one when there is more than one shortest path linking a set of vertices. All shortest paths among various groups must follow one of the sparse inter-group edges if a network comprises communities or groups that are only tangentially connected. As a result, interconnected communities' edges will have significant edge betweenness. Girvan-Newman's algorithm separates these edges from one another and aims to examine the structure of communities (Girvan & Newman, 2002). In this study, for the co-authorship analysis, edge betweenness is used as a clustering method.

4.2.3. Visualization

To determine various measures of the overall network, measurements of the interaction between the different clusters found, or measures of their overlap, network analysis allows us to do a statistical analysis of the maps that are created. Bi-dimensional charts, dendrograms, and social networks are just a few examples of simple visualizations that may be used to depict the beneficial knowledge that can be extracted from data using bibliometric analysis methods (Aria & Cuccurullo, 2017). Bibliometric analysis in this study is visualized by the bibliometrix library.

4.2.3.1. Kamada & Kawai Layout

Kamada & Kawai is a network layout, which regards the "graph theoretic" distance between two vertices in the figure as the desirable "geometric" (Euclidean) distance between them in the associated graph. Kamada & Kawai provide a virtual dynamic system in which each pair of vertices is linked by a "spring" of the desired length and the ideal vertices arrangement is defined as the state in which the system's total spring energy is minimum (Kamada & Kawai, 1989).

4.2.3.2. Fruchterman – Reingold Layout

In the article “Graph Drawing by Force–Directed Placement”, Fruchterman – Reingold offers a template for creating undirected general graphs with straight edges. To create a straightforward, intuitive, theoretically simple, and effective algorithm, their heuristic aims for uniform edge lengths and is developed in similarity to forces in real systems. To map the collaboration network in this study, Fruchterman – Reingold layout is used (Fruchterman & Reingold, 1991).

4.3. Science Mapping

Science mapping is a generic process of domain analysis and visualization. A science mapping study typically includes a body of scientific literature, a set of bibliometric analysis and graphic analytic tools, measures, and indicators that can reveal significant potential

relationships and correlations, and theories of scientific change that can guide the inquiry and perception of graphical academic constructions and evolving trends (Chen, 2017).

Bibliographic coupling, citation analysis, co-citation analysis, co-word analysis, and co-authorship analysis are the approaches that are used in the scientific mapping.

4.3.1. Bibliographic Coupling

Bibliographic coupling is a scientific mapping approach based on the notion that two papers with related references would have related information. Kessler defined bibliographic coupling as "a single item of reference used by two papers defined as a unit of coupling between them" (Kessler, 1963). Bibliographic coupling focuses on categorizing articles into thematic groups depending on shared references, and it's best implemented when it's applied to a certain timespan. The generic formulation can be used to create a coupling network, which is also used in bibliometrix is:

$$B = A \times A^T,$$

where A is a rectangular binary matrix bipartite network, which is a type of complex network in which the nodes are separated into two groups, X and Y, and only connections among nodes in distinct sets are permitted. Rows and columns in matrix A are representing manuscripts and sources. If the paper i has been published in source j, the generic element a_{ij} is 1, otherwise, it is 0. The number of bibliographic couplings between manuscripts i and j is shown by the element b_{ij}.

In bibliometrix, the function biblioNetwork generates the most often used coupling networks: Authors, Sources, and Countries, beginning with a bibliographic data frame. The bibliographic coupling network is calculated using the code below:

```
NetMatrix <- biblioNetwork (M, analysis = "coupling", network = "references", sep = ".")
```

In this study, the bibliographic coupling is done according to the references. Clusters are labeled by title terms in trigrams, and the minimum cluster frequency is 10 percent. Each cluster is labeled with the name of the most significant keyword in the related topic (which is determined by the theme's most central keyword).

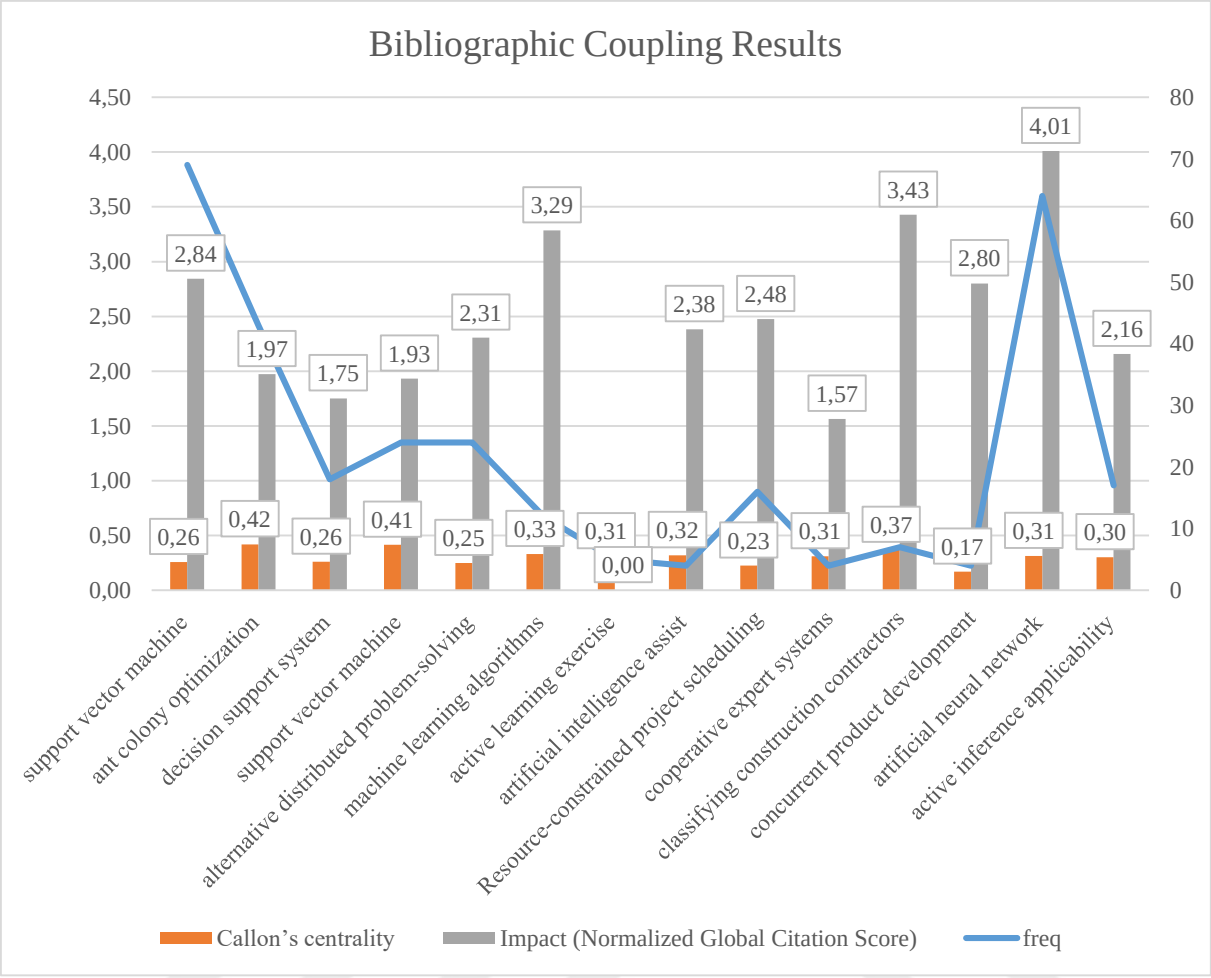


Figure 4.9: Bibliographic coupling results (Source: author's own work)

Figure 4.9 represents the bibliographic coupling results. The orange bar represents the Callon Centrality which is the relevance of the cluster to the domain, and the grey bar represents the impact, which represents the importance of the cluster. It is calculated according to the Normalized Global Citation Score (NGCS). NGCS is a citation frequency metric and it is calculated using the entire Web of Science count at the time the data had been obtained (Philadelphia et al., 2006). The blue line, frequency represents the occurrence of the cluster. On the y-axis, left-hand values represent centrality and impact, while right-hand values represent frequency. As Figure 4.1. indicates that, "Artificial Neural Networks" and "Support Vector Machines" have both high impact and high centrality. Their frequency is also significantly higher than the rest of the clusters, which indicates that papers in these clusters are central points for the project management domain and it suggests these keywords can be a good starting point for further research in the domain.

4.3.1.1. Bibliographic Coupling Thematic Map

According to the Census Dictionary, a thematic map is "the spatial variability of a specific distribution or theme" (Statistics Canada, 2015). To create a thematic map in this study, the "thematicMap" function of bibliometrix is used. The function "thematicMap" generates a thematic map using clustering and co-word network analysis. The keywords and their linkages in a topic form a network graph known as a thematic network. Each thematic network is labeled with the name of the most significant keyword in the related topic.

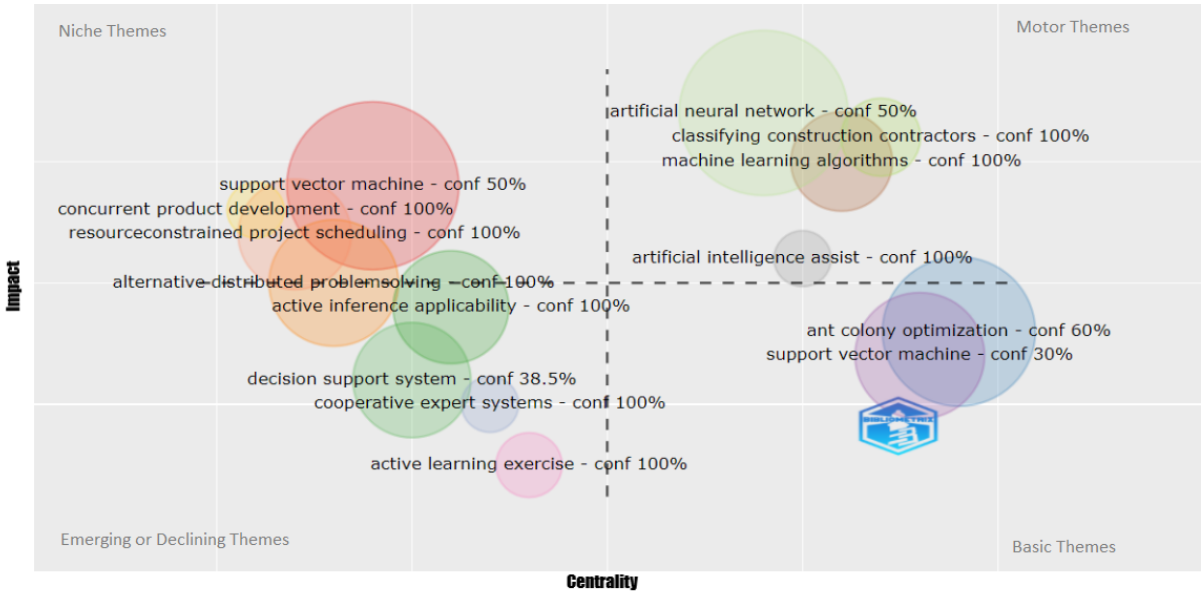


Figure 4.10. Bibliographic coupling thematic map (Source: author's own work)

In Figure 4.10, the bibliographic coupling thematic map by documents is depicted. The x-axis measures Callon's (cluster) centrality (measured by Callon's Centrality index). Callon's centrality is used in the thematic map as an impact index since it measures the importance of the subject by measuring the intensity of a cluster's links with other clusters. The y-axis measures the cluster impact by NGCS. The volume of the shapes represents the frequency of the thematic network.

From this point of view, the left bottom of the map, where keywords have low impact and low centrality, implies that the clusters which are represented by "active inference applicability", "decision support system", "cooperative expert systems" and "active learning exercise" poorly linked with other papers and not highly cited, so they are emerging or declining themes. "Support vector machine", "concurrent product development" and "resource-

constrained project scheduling" clusters are niche themes for the domain, while they have high impact but are cited poorly compared to the other themes. "Artificial neural network", "classifying construction contractors", "machine learning algorithms" and "artificial intelligence assist" are the motor themes of the domain with high impact and high centrality. "Ant colony optimization" and "support vector machine" are the basic themes, while they have high centrality with low impact. "Alternative distributed problem-solving" is the cross-theme between emerging/declining themes and niche themes, referring to the theme as probably an emerging one.

4.3.2. Co-Citation Analysis

Co-citation analysis is a scientific mapping approach that suggests that papers that are often referenced together are thematically comparable.

All the nodes are included in the analysis and the repulsion force, which indicates the repulsion force among network communities (a real number between 0 and 1) is 0,1 (default value). The isolated nodes within the network are removed for visualization, and the minimum number of edges is 3. Kamada-Kawai is used as the layout. Edge betweenness is used as the clustering algorithm.

The generic formulation used to build a co-citation network:

$C = A^T \times A$ where A is a bi-partite network. C is a symmetric matrix.

The code for calculating the co-citation network is as follows:

```
# NetMatrix <- biblioNetwork(M, analysis = "co-citation", network = "references", sep = ".  ")
```

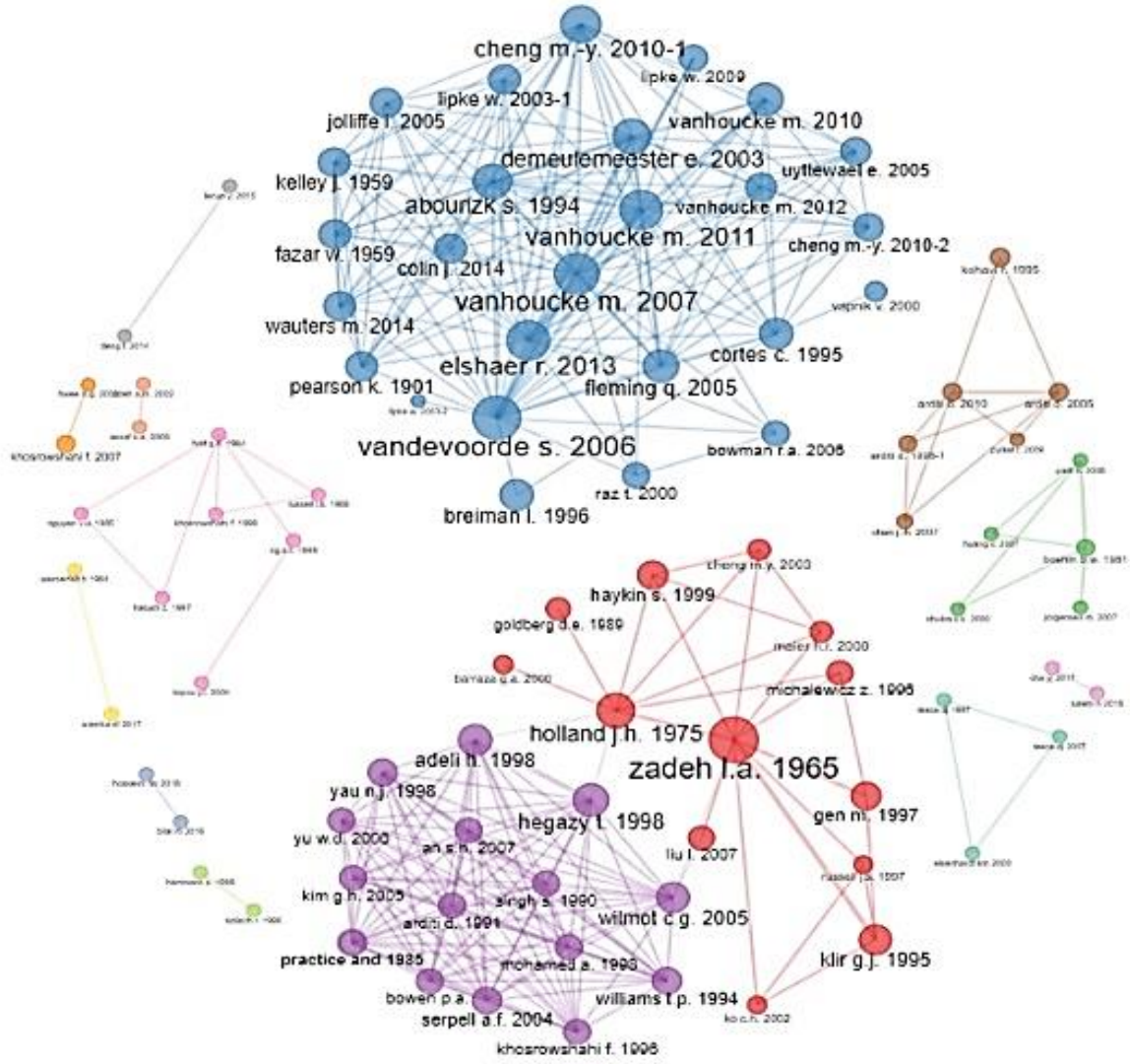


Figure 4.11: Co-citation map (Source: author's own work)

In Figure 4.11, co-citation map is depicted. According to the map and the analysis related to it, papers are categorized under the following themes;

Theme 1 - ("Artificial Intelligence", Red Colored Cluster, N= 13): The first cluster represented by red color has two central points. The first central node to the cluster is a paper called "Fuzzy Sets" (Zadeh, 1965) which coined the term "fuzzy set", written by Lotfi A. Zadeh from Berkeley. It is the most central node with the highest Betweenness Centrality - BC (118,1013707) and Closeness Centrality - CC (0,000179179), along with the highest PageRank (0,017540018). The article is about fuzzy sets, which are sets of elements with varying degrees of membership, and their properties. The second central node is the book named "Adaptation in Natural and Artificial Systems" written by John H. Holland (Holland, 1975). It has the

second-highest BC, CC, and PageRank in the cluster. The book is considered a reference book for Artificial Intelligence. Holland uses adaptation by presenting a mathematical model for it and proved its universality by its application to various domains including artificial intelligence. Considering these two hubs' contents, also the domain of the papers within the cluster, its theme can be labeled as "Artificial Intelligence". Another important node in the AI cluster is "Genetic Algorithms and Engineering Design" (Gen & Cheng, 1997), a book by Mitsuo Gen and Runwei Cheng, recognized specialists in the field of industrial systems applications of genetic algorithms and AI. The book provides a thorough overview of genetic algorithms in industrial engineering and operations studies, including the techniques and approaches to production. "Fuzzy Sets And Fuzzy Logic Theory And Applications" (Klir & Yuan, 1995) is another important node in the cluster. This book highlights the achievements made in the fields of fuzzy set theory & fuzzy logic between 1988 and 1995. The book includes both academic breakthroughs in these fields and a wide range of implementations of fuzzy sets & fuzzy logic. Within the cluster, there is the article "Improving Cost Estimates of Construction Projects Using Phased Cost Factors" (L. Li & Kai, 2007) which shares a citation with Wilmot & Mei's "Neural Network Modeling of Highway Construction Costs" paper. The paper aims to reveal the key aspects for accurate prediction at different phases of typical construction projects.

Theme 2 – ("Project Management", Blue Colored Cluster, N= 26): The second cluster represented by blue color has the paper "A comparison of different project duration forecasting methods using earned value metrics" (Vandevoorde & Vanhoucke, 2006) as the central node since it has the highest BC (60,76380952) and CC (0,000174307) amongst the cluster, while it has also the highest PageRank (0,017417926). The main theme for the paper is "Project Management", which is a good candidate for the label of the cluster, while the sub-theme of it can be labeled as project duration forecasting. Another central node to the theme is the "Support-Vector Networks" (Cortes et al., 1995) article by Corinna Cortes, which introduces the support-vector network as a learning machine for two-group identification tasks. Support vector networks are the earlier version of support vector machines (SVM), which are used in classification problems in project management. "Impact of Sensitivity Information on the Prediction of Project's Duration Using Earned Schedule Method" (Elshaer, 2013) is the third most central node in the cluster. The article analyzes the effect of various activity-sensitivity metrics on the ESM method's predicting performance.

Theme 3 – ("Software Development", Dark Green Colored Cluster, N= 5): The third cluster, represented by dark green color, has one central node which is a book written by

Barry W. Boehm, “Software Engineering Economics” which aims to utilize economic analysis in software engineering decision making (Boehm, 1984). Regarding the context of the book, this theme is labeled as “Software Development”

Theme 4 – (“Neural Network and Construction Project Management”, Purple Colored Cluster, N= 15): The fourth cluster is represented by the purple color. The most central node of the cluster is the paper called “Neural Network Modeling of Highway Construction Costs” (Wilmot & Mei, 2005). The paper aimed to create a method for estimating the escalation of highway building expenses over time. As a result, an artificial neural network model that correlates overall highway construction costs was developed. The second most central node is “Towards effective design coordination: a questionnaire survey” (Hegazy et al., 1998), which is an article by Tarek Hegazy. The article describes the findings of a questionnaire study done across 12 major design companies in Canada in an attempt to build a systematic strategy for enhancing design coordination. The article is important in its findings since it is an earlier example of suggestions for using computer applications to improve management, in terms of communication in this article. This paper also serves as a bridge between Theme 1 and Theme 4, as it has co-citation with “Adaptation in Natural and Artificial Systems”, John Holland’s book. Another linkage to Holland’s book is the third most central node in the cluster, “Regularization Neural Network for Construction Cost Estimation” (Hojjat & Mingyang, 1998). In the article, a regularization neural network is proposed, as well as a neural network design, for estimating the cost of building projects.

Theme 5 – (“Construction Cash Flow Management”, Dark Orange Colored Cluster, N=2): The fifth cluster is represented by two nodes. The first is “A Decision Support Model for Construction Cash Flow Management” which emphasizes the significance of cash flow forecasting and management, and explores a variety of forecasting models for project expenditure patterns (Khosrowshahi & Kaka, 2007). The second node is “Model on cash flow forecasting and risk analysis for contracting firms” which proposed a model named Cash Flow Forecasting System, a model that was created to assist in forecasting cash flows and analyzing risk variables (Ng & Tiong, 2002).

Theme 6 – (“Classifying Construction Expertise”, Brown Cluster, N= 6): Sixth cluster has two central nodes. The first central node is the article “Lessons learned system in construction management”, which aims to design lessons learned system that allows a construction firm to capture, archive, access, and communicate construction management

lessons learned (Arditi et al., 2010). To provide such a system, Arditi created a database called 'CMAID', which enables the simple submission and retrieval of construction management lessons. The second central node is the article "Issues in Subcontracting Practice", which covers the issues which occur during subcontracting period via an exhaustive survey administered to the relevant parties. The theme, in general, can be labeled as "classifying construction expertise", since the papers within the cluster try to classify and organize the expertise and knowledge within the construction sector.

Theme 7 – ("Classifying Contractors", Magenta Cluster, N=6): The seventh cluster has two central nodes. The first central node is the article "Factors Influencing U.K. Construction Clients' Choice of Contractor", which is trying to define, apart from cost, which factors affect clients' choice when choosing a contractor. The second node is the article "Client and consultant perspectives of prequalification criteria", which analyzes variation in selection criteria used in contractor prequalification by various client and consultant organizations while trying to provide a standard for prequalification. Hence articles in this cluster focus on classifying the contractors, "Classifying Contractor" theme is chosen for this cluster.

Theme 8 – ("Neural Networks", Grey Cluster, N=2): The eighth cluster has two nodes in it. The first node is the "Deep learning" paper of Yann André LeCun, who is famous for his articles on neural networks and machine learning. The article explains "deep learning" and explores its areas of use while reviewing machine learning techniques (Lecun et al., 2015). The second node, "Deep Learning: Methods and Applications" presents a comprehensive introduction to deep learning techniques and their applicability to a wide range of signal and information processing problems (Deng & Yu, 2014). Since all the nodes are endpoints, their BC is 0.

Theme 9 – ("Dynamic Capabilities", Cyan Cluster, N=3): The ninth cluster has three nodes. The first node is "Dynamic Capabilities and Strategic Management", which is an article in which David J. Teece proposed a dynamic capabilities framework. The dynamic capabilities framework examines the sources and strategies of wealth generation used by private enterprises in fast-changing technology contexts (Teece et al., 1997). The second node, "Dynamic Capabilities: What are They?" focuses on dynamic capabilities, which are "a set of specific and identifiable processes such as product development, strategic decision making, and alliancing" and resource-based view (RBV) of the firm (Eisenhardt & Martin, 2000). The third node is "Explicating Dynamic Capabilities: The Nature and Microfoundations of (Sustainable)

Enterprise Performance", describing the structure and micro-foundations of the skills required to sustain outstanding company performance in a free market with continuous innovation and internationally distributed sources of invention, innovation, and manufacturing capacity. The answer to the question is dynamic capabilities, as follows "Dynamic capabilities enable business enterprises to create, deploy, and protect the intangible assets that support superior long-run business performance" (Teece, 2007). Betweenness centrality among clusters is 0 since the cluster is triangular shaped and every node is an endpoint.

Theme 10 – ("Construction Delays", Light Orange, N=2): The tenth cluster has two nodes. The first node is "Causes of delay in large construction projects". In the article, to establish the reasons for delays, a survey on the time performance of several types of building projects in Saudi Arabia was done. The finding is that change in contracts is the main issue (Assaf & Al-Hejji, 2006). The second node is "Causes of construction delay: traditional contracts", which is another paper on the same issue, trying to identify reasons for the delay in construction (Odeh & Battaineh, 2002).

Theme 11 – ("Construction Industry Literature Review", Parliament, N=2): The eleventh cluster has two nodes. The first node is "Critical evaluation of off-site construction research: A Scientometric analysis", which is the first bibliometric research on the current state of off-site construction research (Hosseini et al., 2018). The second node is, "Big Data in the construction industry: A review of present status, opportunities, and future trends" which gives a comprehensive examination of the Big Data literature, focusing on the use of Big Data techniques in the construction business (Bilal et al., 2016).

Theme 12 – ("Deep Learning in Construction", Pink, N=2): The twelfth cluster has two nodes. First is "Deep Learning-Based Crack Damage Detection Using Convolutional Neural Networks", an article that presents a vision-based technique for identifying concrete fractures without computing the fault attributes based on a deep architecture of convolutional neural networks (Cha et al., 2017). The second node is "Emerging artificial intelligence methods in structural engineering", a review article discussing strategies for using the AI technologies in structural engineering that have been developed over the previous decade (Salehi & Burgueño, 2018). Deep learning in construction is the main theme for this node.

Theme 13 – ("Resource-Constrained Project Scheduling Problem", Green, N=2): The thirteenth cluster has two nodes. The first is "A Competitive Genetic Algorithm for Resource-Constrained Project Scheduling" which take the resource-constrained project

scheduling problem with makespan minimization as the goal, and offers a new genetic algorithm method for solving it (Hartmann, 1998). The second node is "Serial and parallel resource-constrained project scheduling methods revisited: Theory and computation", in the article the traditional resource-constrained project scheduling problem is considered and a parallel and serial scheduling strategy is used (Kolisch, 1996).

Theme 14 – ("Resource-Based Performance Analysis", Yellow, N=2): The fourteenth cluster has two nodes. First is the "Big data analytics and firm performance: effects of dynamic capabilities" article, which offers a big data analytics capability model based on the resource-based approach and the literature on big data analytics, information system (IS) success, and the commercial value of information technology (IT) (Wamba et al., 2017). Second is the article "A Resource-Based View of the Firm", which investigates the utility of analyzing organizations from the resource side rather than the product side (Wernerfelt, 1984).

4.3.3. Co-Word Analysis

The purpose of a co-word analysis is to identify the concept of a framework in a bibliographic set using word co-occurrences. The approach of co-word analysis analyses the actual content of the publication.

The generic formula that can be used to create a co-word network is

$$B_{coc} = A' \times A$$

$$A = Document \times Word\ matrix$$

In the Word matrix, the terms are frequently generated from "author keywords." However, the words are taken from "article titles", "abstracts" and "full texts" in the absence of author keywords (Aria & Cuccurullo, 2017).

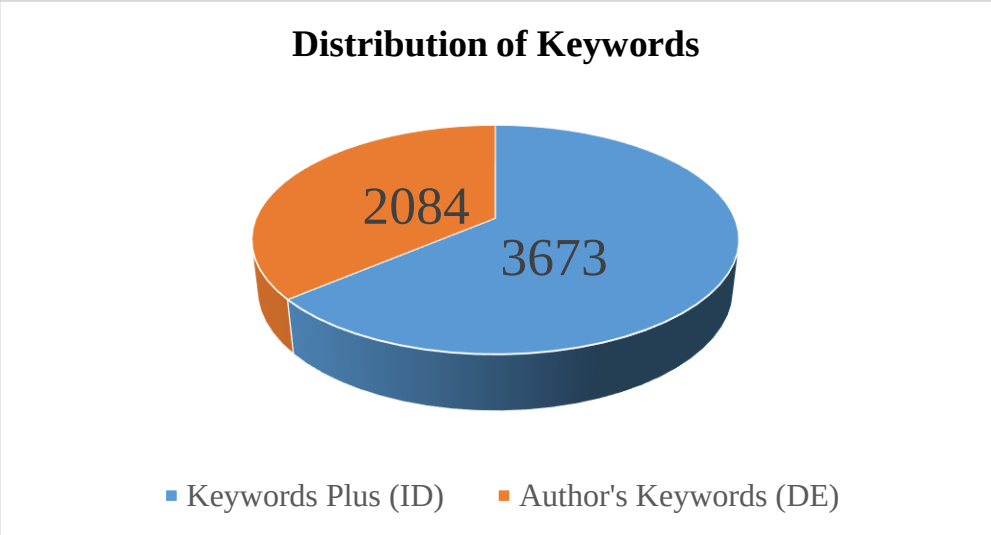


Figure 4.12: Distribution of keywords (Source: author's own work)

Figure 4.12 presents the content of the documents that are subject to analysis. 2084 Keywords Plus (with the abbreviation of ID in data) and 3673 Author's Keywords (with the abbreviation of DE in data) exist, however in this study, Keywords Plus is used for co-word analysis, since it captures both "author keywords" and keywords that may be related but not included in author keywords.

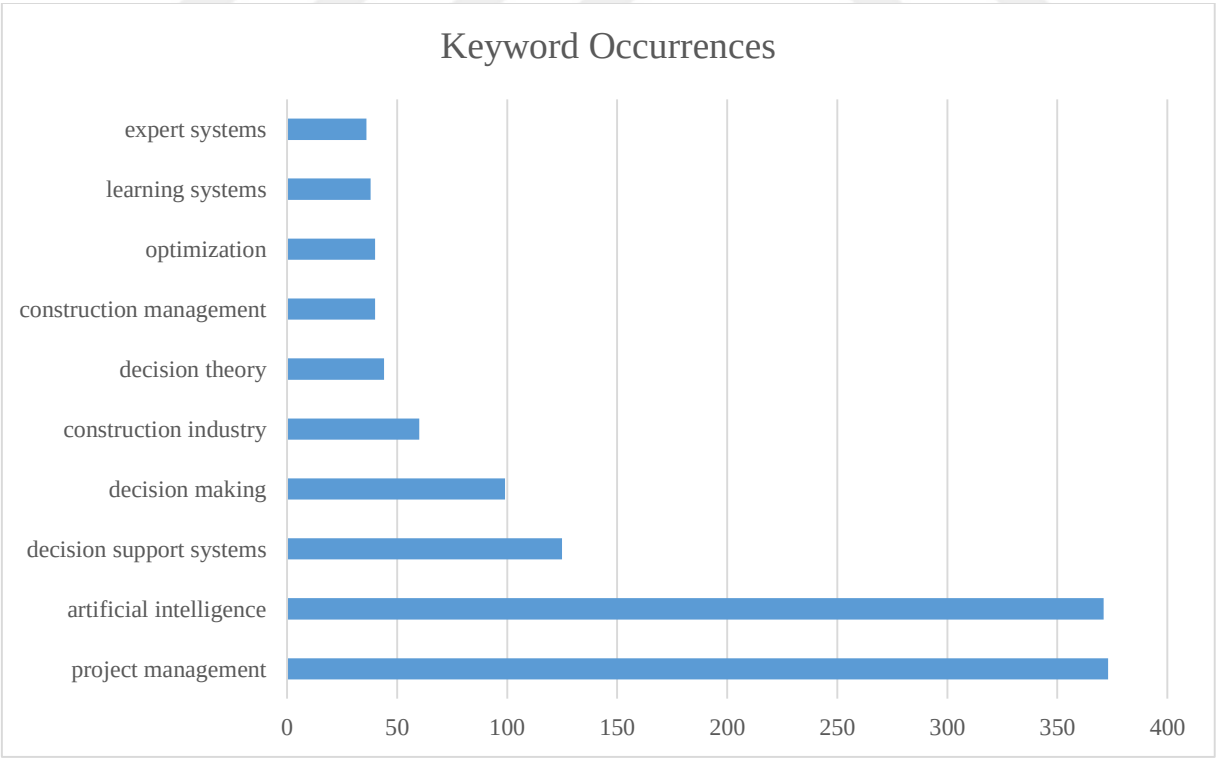


Figure 4.13: Most relevant keywords (Source: author's own work)

In Figure 4.13, the Most Relevant Keywords within author keywords are depicted. They are, in order, “project management, artificial intelligence, decision support systems, decision making, construction industry, decision theory, construction management, optimization, learning systems, expert systems”. In keyword occurrences, AI and PM are the most occurred ones as expected and followed by DSS and decision making, which are the backbone of management. 5th and 7th most occurred keyword is construction industry and construction management, and it is intuitive since project management originated from the construction sector.

4.3.3.1. Co-Word Analysis Thematic Map

Using co-word analysis, the topic areas that defined fundamental and applied research at different times are determined in this study. While explaining the content of the ongoing study, two indicators used to place each particular subject in its associated research network (centrality) and determine its degree of internal development (density) were also employed, which were first introduced by Michel Callon (Callon et al., 1991).

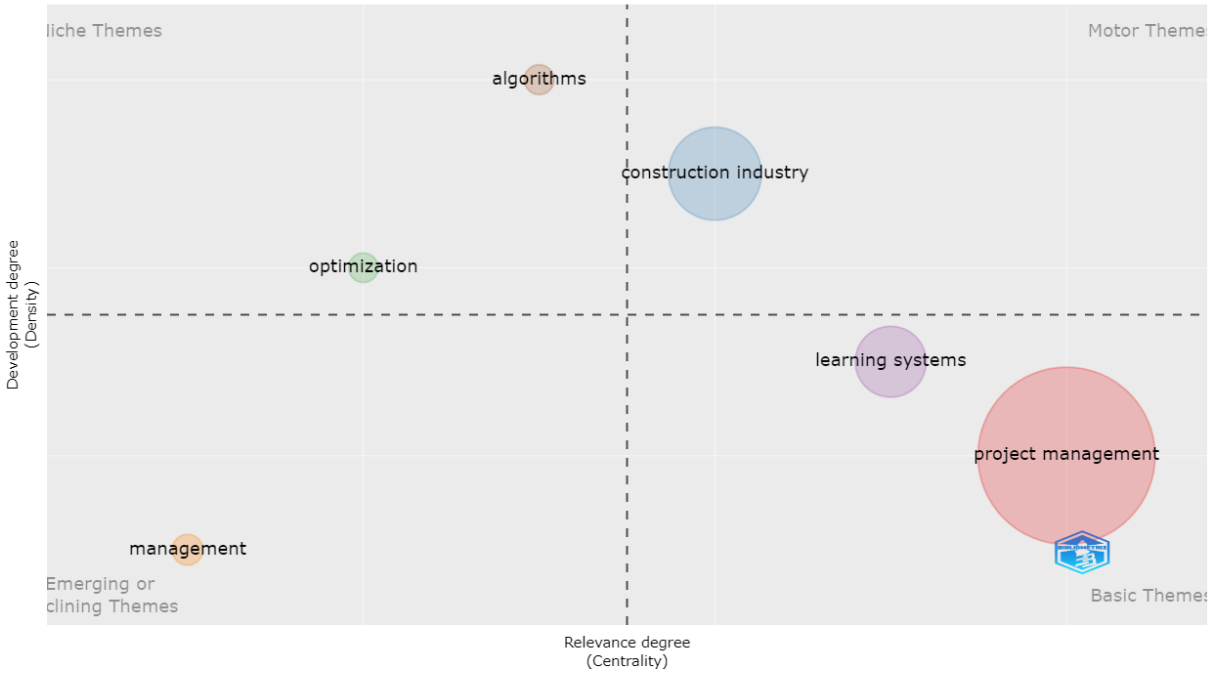


Figure 4.14: Co-word thematic map (Source: author’s own work)

In Figure 4.14, the Thematic Map of project management according to the co-word analysis is presented. The thematic map is created by plotting the descriptive themes of a

domain in a two-dimensional map using a co-occurrence keyword network. Keywords are extracted from Keywords Plus, and the minimum cluster frequency is 10 per thousand documents.

Table 4.3. Thematic map data

Cluster	Theme Class	Callon Centrality	Callon Density	Cluster Color
project management	Basic	18,27	39,89	red
learning systems	Basic	13,24	47,46	Purple
construction industry	Motor	13,21	60,24	blue
optimization	Niche	10,34	48,98	green
algorithms	Niche	10,82	75,41	brown
management	Declining	4,16	35,56	orange

In table 4.3, Thematic Map Data is represented. According to the map and the data, the themes are divided into four as follows;

Basic Themes: the themes with high relevance and low development degree are labeled as basic themes. These themes lay the basis for the field. “Project Management” and “Learning Systems” are the basic themes of the domain in this study. Basic themes have the highest Callon Centrality, (18,27 for Project Management and 13,24 for Learning Systems). It demonstrates the high intensity of the links of the theme with other themes and the high importance of the domain. A learning system is, as Barker defined, “a collection of artifacts that are ‘brought together properly’, to create an environment that will facilitate various types of the learning process.” (Barker, 2009). Learning systems may take many various forms, including books, mobile apps, computers, online forums, schools, and universities. The theme covers human resource management and information management with innovative papers that propose learning systems as solutions to the project managers face (Trappey et al., 2006; Wamba et al., 2017).

Motor Themes: the themes with high relevance and high development degree are labeled as motor themes. As historical facts suggested, the motor theme of the domain is the “construction industry”. Construction project management is an issue of information, or rather, a problem of the lack of information needed to make decisions. Decisions must be taken to keep the project moving forward, even if all the information needed to make the choice is accessible. Construction decision-making is thus about making solid decisions rather than creating ideal

ones (Baiyi & Austin, 2014). As a result, project management is in a close relationship with construction projects in the literature. As well as being central with 13,21 Callon Centrality, its density is also very high (60,24), implying highly linked with other themes in the domain.

Niche Themes: The themes with low relevance and high development degree are labeled as niche themes. The niche themes of project management are "optimization" and "algorithms". The theme "optimization" includes papers about risk analysis and strategic planning, which becomes more and more important after COVID and improved significantly using AI (Z. Li & Mo, 2020b). The "algorithms" theme includes papers about pattern recognition, information retrieval, image enhancement, and feature extraction (Khosrowshahi & Kaka, 2007). While both themes have lower centrality comparing the rest of the themes (10,34 for optimization and 10,82 for algorithms), the "algorithms" have a high Callon density, which implies the theme is highly connected. Indeed, the methods used in the "algorithms" themed papers are vastly used in the whole domain, however, they are far from being central to the domain, which makes them niche themes.

Emerging or Declining Themes: the themes with low relevance and low development degree are labeled as emerging or declining themes. Management is a declining theme for the domain, as there is a shift from sole "management" to "project management" as project management is defined as a term, and it is widely used after the 21st century. As Callon Centrality measures the intensity of linkage of themes with other themes, lower centrality for the term "management" (4,16) indicates that it does not have strong connections to the other publications, as can be traced by the publications themselves. Management is a generic label for the cluster as the term "management" itself is generic and a common term amongst the cluster, but in fact, the theme is mostly related to information management. From the 21st century onwards, papers with "project management" theme diversified from the papers that have "design", "innovation management", "productivity" and "technology management" themes. Callon's Density of the theme is 35,56, which is the lowest in the domain, which supports the inference of the theme's decline, which also implies the emergence of project management as a theme.

4.3.4. Thematic Evolution Analysis

Thematic evolution analysis is determining the key broad thematic areas of the research subject, their origin, and their interconnections by analyzing the evolution of the detected themes through several subperiods researched (Cobo et al., 2011). Using the findings of performance analysis and science mapping, thematic evolution analysis is conducted in this study for project management in the era of AI between 1987 to 2022.

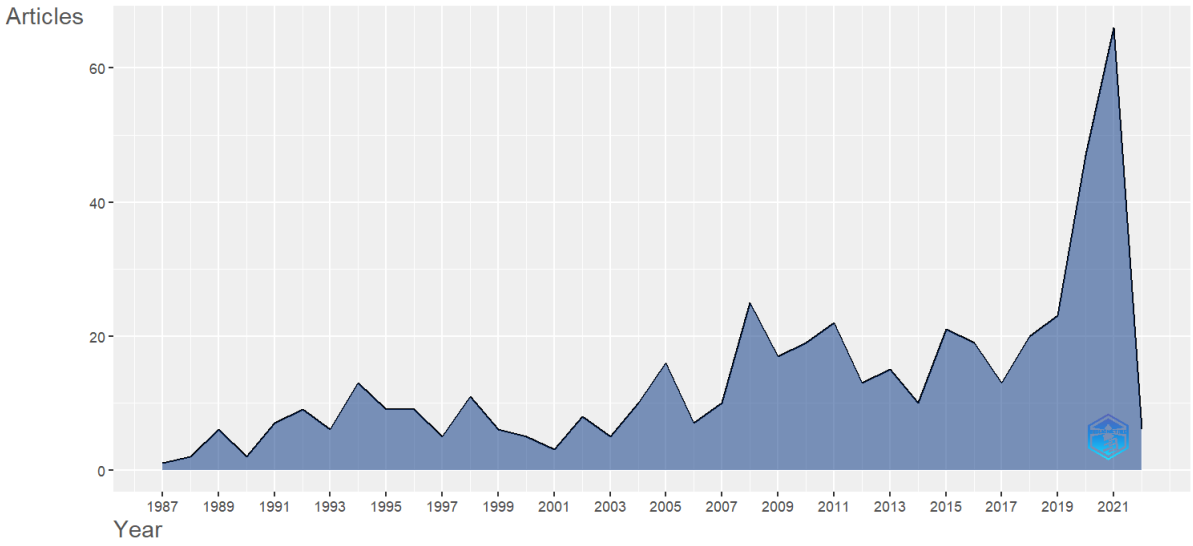


Figure 4.15: Annual scientific production (Source: author's own work)

When we observe Figure 4.15, the Annual Scientific Production, we see that publications tend to increase overall despite some decreases in certain years between 1987-1999. Total Publications in that period is 86. From 1999 to 2001, the domain suffered a loss in terms of publications, then it continues to rise after 2001 up to 2009. 2000 – 2009 period has 106 publications in the domain. From 2009 onwards, although in some years with decline, in 2019 and 2020, the domain has peaked in terms of production, which sums total publications of the era to 294.

Table 4.4: Total publication data

Year	Total Publications
1987 - 1999	86
2000 - 2009	106
2009 - 2021	294

(Source: author's own work)

To conduct thematic evolution analysis, the timeline is divided into three different sub-periods. As Table 4.4 indicates, three sub-periods are chosen (1987-1999, 2000-2009, and 2009-2022) and the evolution of themes amongst these periods are analyzed according to the Inclusion Index and Stability Index.

1987-1999 Thematic Map

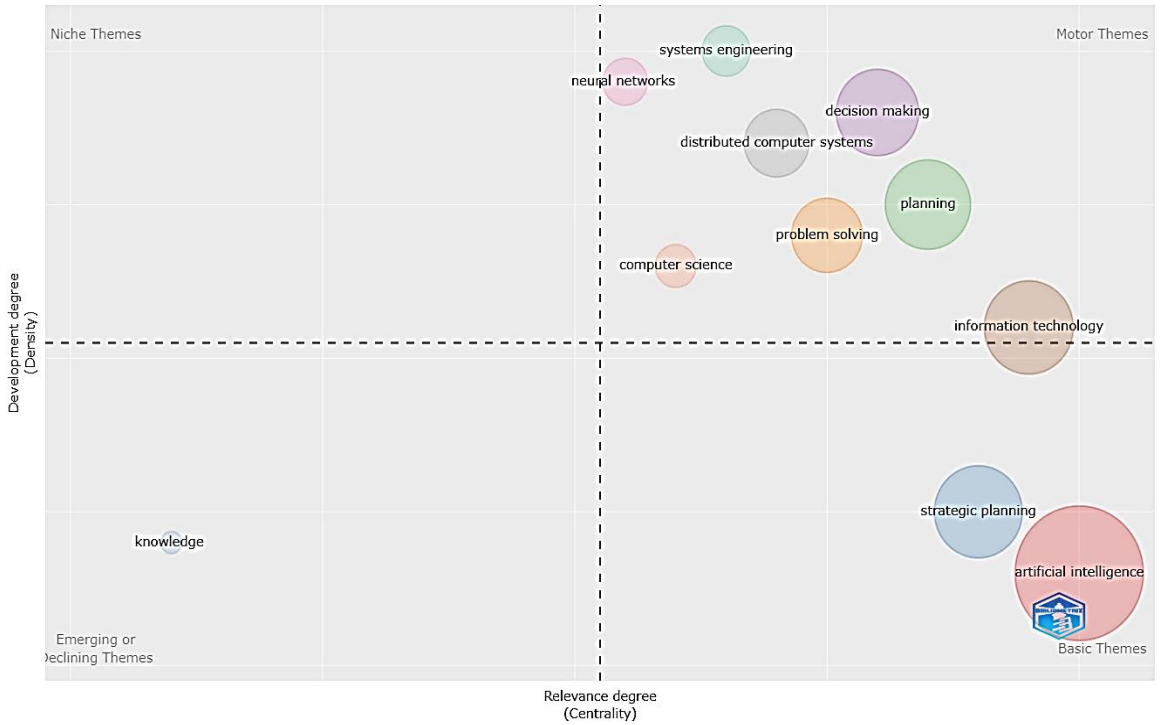


Figure 4.16: 1987-1999 thematic map (Source: author's own work)

In the first sub-period, as Figure 4.16 indicates, "strategic planning", which will later transform to project management was the basic theme, along with "artificial intelligence", both of the themes having high Callon Density and Centrality. One of the earliest papers that sets an example for basic themes is "Computer-Generated Explanations in Project Management

Systems", which examines the possibilities for automated explanatory skills in project management systems, as well as various ways for generating them, such as using natural language and images created by a computer (Steven & Chris, 1991). The authors anticipated that the future of the Project Management System to have automatic explanation capabilities, which is an accurate prediction made in 1990. The paper suggested AI (which is referred to as automated explanation facilities in the paper) should significantly increase the effectiveness of Project Management Systems by lowering the research burden on project managers, which is a common perspective in the papers on the same theme.

Neural networks, computer science, decision making, problem-solving, systems engineering, planning, and distributed computer systems come out as motor themes that share common instruments. An example of the case might be the paper of Badiru & Sieger, which presents an artificial neural network (ANN) model for the financial evaluation of risky projects (Badiru & Sieger, 1998). By combining traditional simulation with neural network techniques, Badiru & Sieger suggest that additional forecasting capability can be produced, according to the results of the neural network model. For scenarios not in the training set, the neural model could predict simulation output depending on the given values with high accuracy. This enabled an examination of the investment project's future performance without the need for extra costly and time-consuming simulation tests.

2000 - 2009 Thematic Map

In Figure 4.17, a thematic map between 2000-2009 is depicted. Beginning with the 21st century, "project management" is starting to dominate the domain, being a basic theme with high Callon Centrality and Callon Density along with "decision support systems". The study by Ko & Cheng is good for the intuition of the era for both of the themes (Ko & Cheng, 2007). It presents an Evolutionary Project Success Prediction Model (EPSPM) to continuously forecast project success. The model is important to understand the thematic background of the era since it was created using a combination of genetic algorithms, fuzzy logic, and neural networks. Learning systems and learning algorithms, as can be seen in Figure 4.17, is niche themes since as they have high development degrees, they have lower relevance degree than other themes. The reason is that these themes are the novel themes that enter the domain and the position of learning systems implies that the theme being on the edge of motor and niche themes, is a niche but highly developing theme, a candidate to be the basic theme in the long run.

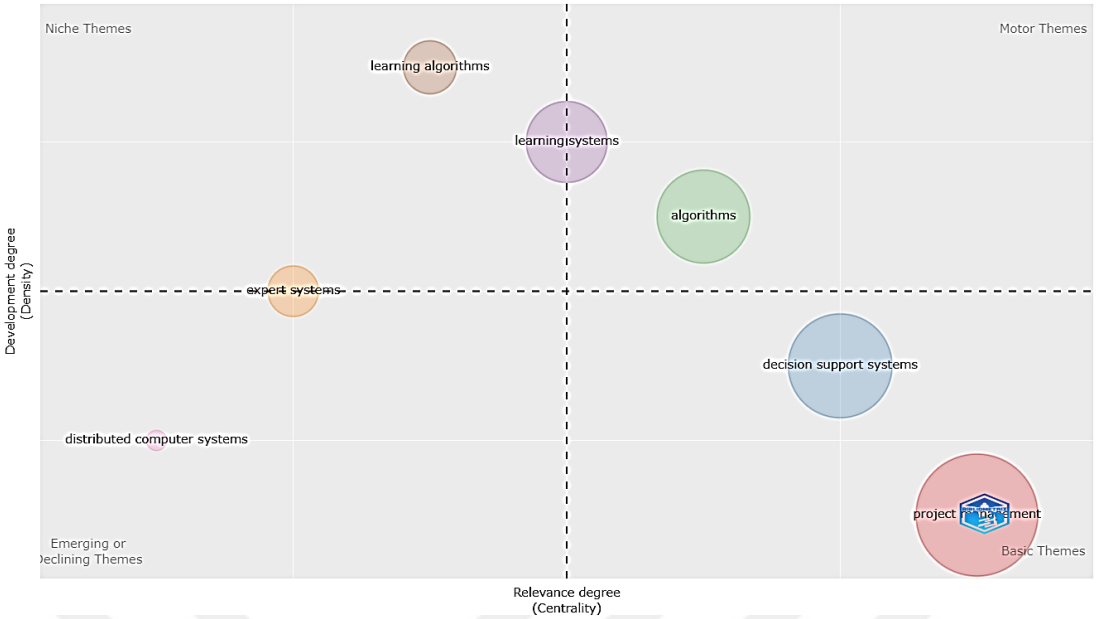


Figure 4.17: 2000 – 2009 thematic map (Source: author's own work)

Distributed computer systems, while being in a motor theme between 1987 – 1999 era, between 2000 – 2009, it is classified as emerging or declining theme being low developed and low relevant. However, since it was a motor theme in a prior era, it is an indicator that this theme is a declining theme, while the theme exists in Figure 4.17, it is absent in Figure 4.18. It has been observed that distributed computer systems theme is transformed into the project management theme.

2009-2021 Thematic Map

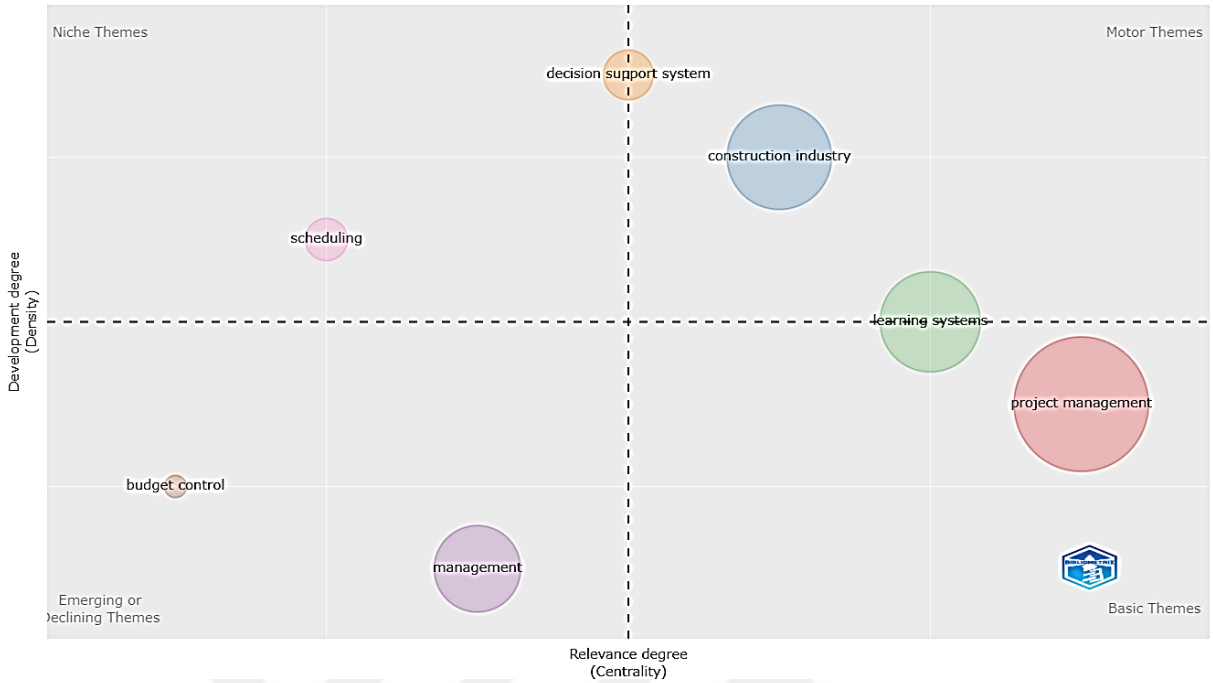


Figure 4.18: 2009 – 2021 thematic map (Source: author's own work)

In Figure 4.18, a thematic map between 2009-2021 is presented. Between 2009-2021 Project management and Learning Systems are the basic themes for the era. Eric Buah's study is one of the studies that capture the basic themes of the era, which offer an AI-powered communication and participation mechanism as an alternative to the standard communication and participation strategy for energy projects, to address the constraints of the traditional strategy (Buah et al., 2020). Buah claimed that AI-powered management agent provides an objective decision-making environment. However, despite the benefits, its fundamental flaw is that it lacks human interaction while interacting with users. As an example, in the case of a chatbot, which is a chat agent that acts like a human, it will never be capable of replacing the human element in traditional engagement methods. As a result, Buah stated that the suggested methodology should be viewed as a supplement to the traditional technique rather than a substitute.

Yaseen and his colleagues' paper is one of the papers that reflects the motor themes of the era. In the paper, they aim to develop a hybrid AI model for delay problem prediction (Yaseen et al., 2020) based on delay causes, an analytical instrument capable of estimating the extent of delay in construction projects has been presented in the article and the findings

demonstrate the AI-based model's superior capacity to manage the nonlinearity and complexity of data in the construction industry.

When Figure 4.18 is observed it is seen that, the “decision support system”, which was a basic theme in the prior era has moved to the intersection between motor and niche themes. As it loses its relevance and development, it is safe to claim that the theme is declining. “Scheduling” has emerged as a niche theme for the era, which is a critical issue for modern project management.

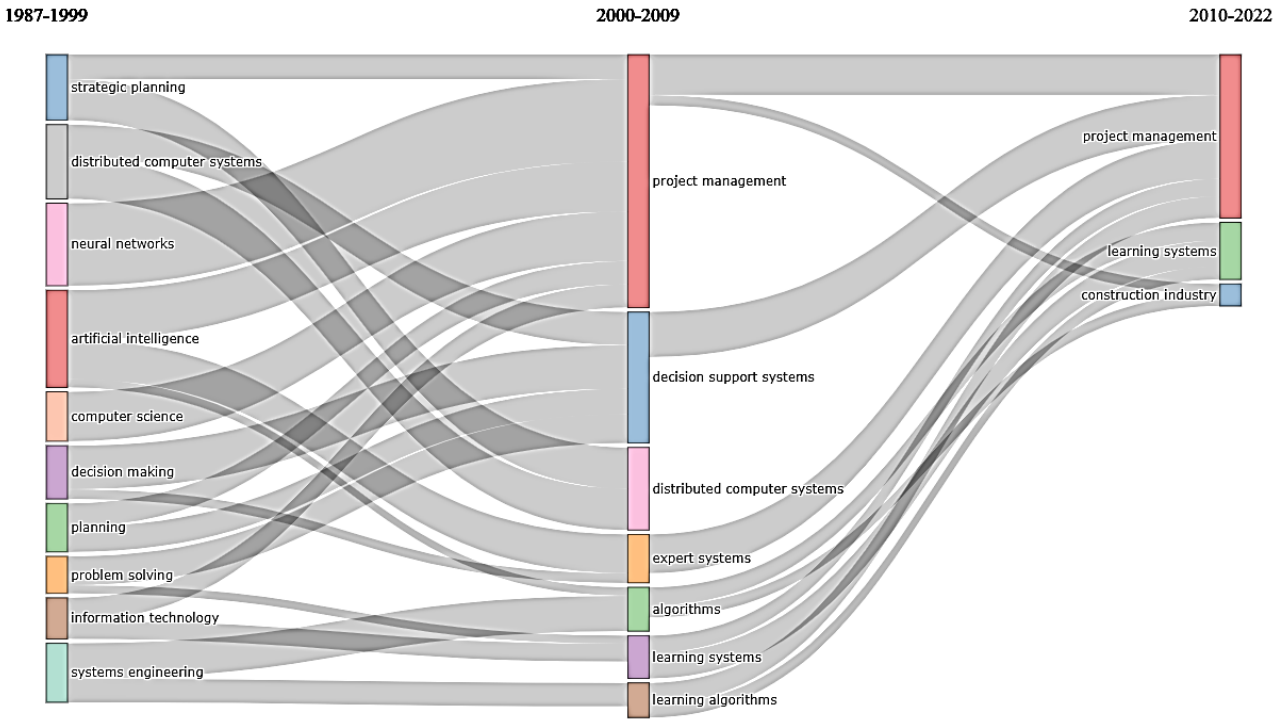


Figure 4.19: Thematic evolution (Source: author’s own work)

All in all, Figure 4.19 lays out the thematic evolution of the era between 1987-2022. The thickness of the lines is indicated by Weighted Inclusion Index (WII), stronger links are represented by thicker lines. The Stability Index (SI) in the table represents the consistency of the theme in the next period, which suggests lower SI comes with a higher paradigm shift. As can be observed from the table, all themes have a stability index lower than 0,2, which implies that themes under the domain are subject to great shift, excluding a couple of basic themes like

project management and decision support systems, even which are subject to change at some point. From 1987 – 1999 to 2000-2009, a couple of great shifts mentioned are;

- From strategic planning, two branches are going to project management and decision support systems, which implies after project management emerged as a research domain as itself, more papers are attributed to the domain instead of "strategic planning".
- "Neural Networks" and "Computer Science" themes are also converged into project management, as many of the implementations are tagged under project management after 2000. As implications from the 2010-2022 era also point that, project management become an umbrella keyword and a common theme for studies related to strategic planning, neural networks, artificial intelligence, and computer science.
- "Decision making", "problem-solving" and "planning" converged into another umbrella term, "decision support systems".

From 2000-2009 to 2010-2022 era, significant changes are;

- The "Decision support systems" theme is converged into the "project management" theme.
- The "Distributed computer systems" theme is discontinued after 2009.
- "Expert systems" theme merged into "project management"
- "Algorithms" theme split between "project management" and "learning systems"

Where N represents years, the numerator indicates the number of documents that remain in the cluster after N years, while the denominator reflects the total number of different documents that appear in the cluster sequence (Small, 1977).

4.3.5. Co-Authorship Analysis: Collaboration Network

The definition of a collaboration network by Batagelj is as follows; “A collaboration network is the set of network’s nodes consisting of authors. There exists an edge (undirected link) between authors “u” and “v” if and only if they produced a joint work (paper, book, report, etc.). Its weight “w (u, v)” is equal to the number of works to which “u” and “v” both contributed.” (Batagelj & Cerinšek, 2013). In other words, “A scientific collaboration network is one in which the nodes are authors and the links are co-authorships, as the latter is among the most well-documented kinds of scientific collaboration” (Schubert, 2005). According to Schubert, International co-authorship reflects collaboration adequately. The following code is used in bibliometrix for creating a country collaboration network:

```
M <- metaTagExtraction(M, Field = "AU_CO", sep = ";")

NetMatrix <- biblioNetwork(M, analysis = "collaboration", network = "countries", sep = ";")

net=networkPlot(NetMatrix, n = dim(NetMatrix)[1], Title = "Country Collaboration", type = "circle", size=TRUE, remove.multiple=FALSE,labelsize=1)
```

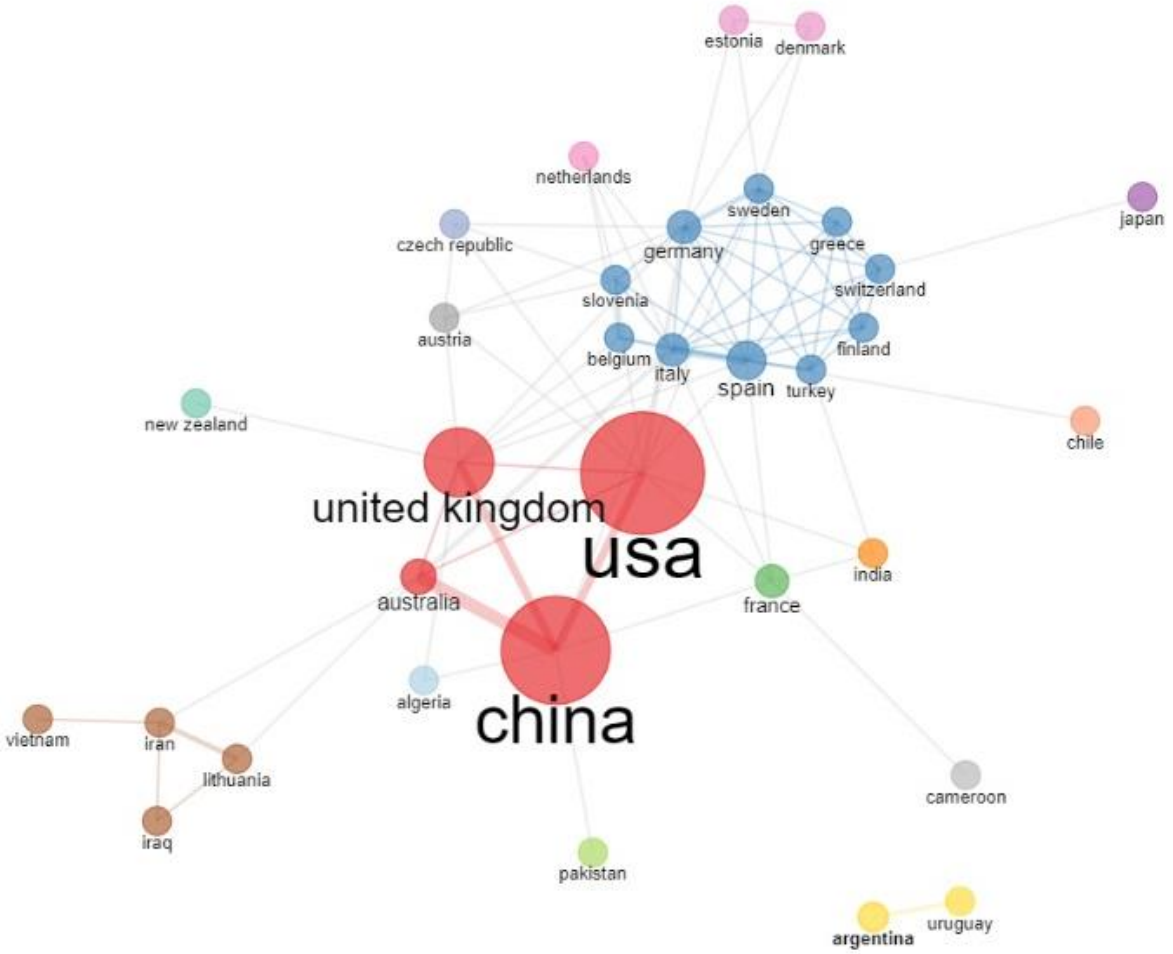


Figure 4.20: Scientific collaboration network (Source: author's own work)

In Figure 4.20, the volume of the circles represents researchers and the links between them represent co-authorship. Isolated nodes are removed for simplification. USA, China, the United Kingdom, and Australia has a co-authorship cluster, depicted in red. According to the performance analysis in section 4.1.1, 10 of the most productive author in the field is affiliated with China, and 4 of the most productive author is affiliated with the USA. There are several intuitions behind it. One of them is the sectoral advantage of these countries. Although the motor themes of the project management domain shifted in the last 20 years to machine learning systems and artificial intelligence, the domain originated from construction management. USA and China are the top countries in terms of value added by the construction sector from 1987 up to now, in 2019 China's added value by construction is 869 billion dollars, while USA's added value by construction is 834 billion dollars (*UNdata | Value Added by Industries at Current Prices (ISIC Rev. 4)*, n.d.). The top scientist from the domain is from the construction sector as well, and they are dominating the domain and having strong co-authorship links with

each other. Another reason is geographical and socio-economic proximity. As Katz proved and formulated in the paper "Geographical Proximity And Scientific Collaboration", geographical, financial, social, and linguistic characteristics have a significant impact on the degree of research collaboration (Katz, 1994). As Katz suggested, following the same principle above, with a strong construction industry as a starting point followed by AI-empowered project management, European researchers formed the blue cluster and they are also strongly connected to the red cluster. There are also several outer smaller clusters and nodes connected to clusters or nodes. There is also a yellow cluster, which is disconnected from the network and is formulated by two nodes, Argentina and Uruguay.

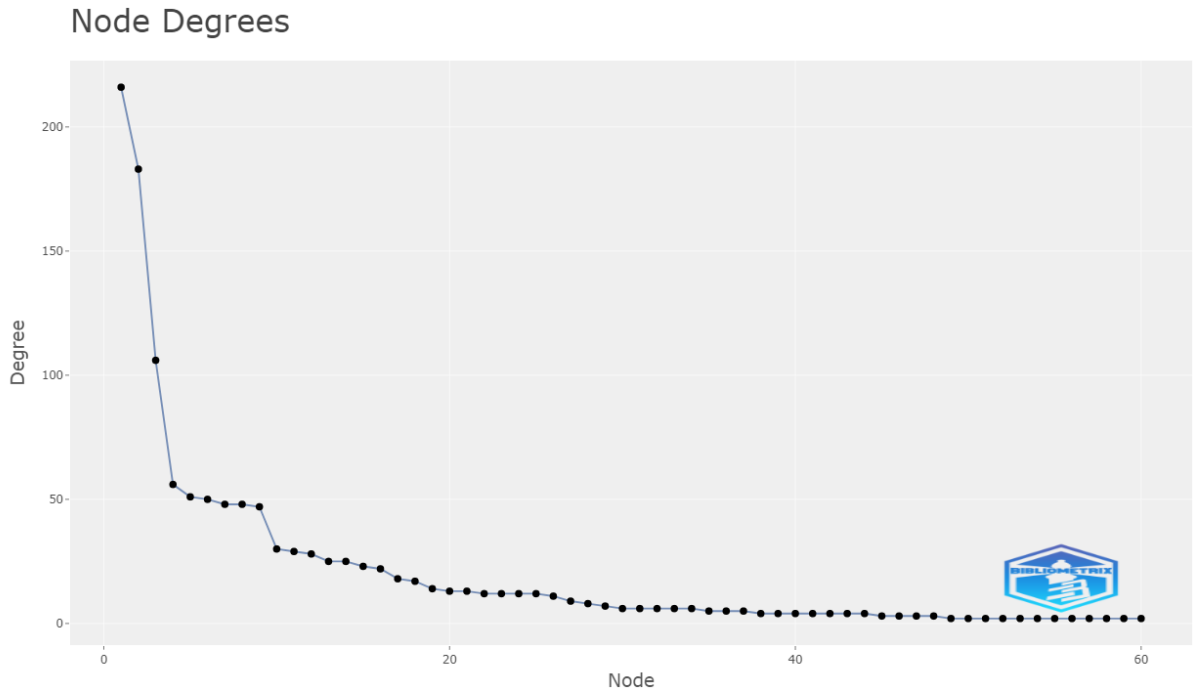


Figure 4.21: Node degrees (Source: author's own work)

Figure 4.21 proves Barabasi's theorem about scientific networks, which is that the network follows the power law and in the network, hubs, and connectors exist. While the x-axis shows the collaboration As he suggested, in the project management network there are also a few hubs that exist, and as suspected, they are the most productive authors. Professor Min-Yuan Cheng and Professor Jui-Sheng Chou from the National Taiwan University of Science and Technology, and Professor Tarek Hegazi from Waterloo University are scientific hubs that connect many authors, hence countries, together.

Table 4.5. Scientific collaboration network results (Source: author's own work)

Node	Cluster	Betweenness Centrality	Closeness Centrality	PageRank Score
China	1	48,52539683	0,008	0,06509927
USA	1	59,80873016	0,008474576	0,057488929
United kingdom	1	59,22698413	0,008333333	0,053159073
Australia	1	104,1428571	0,008	0,049066069
Spain	2	58,8468254	0,008403361	0,066226182
Germany	2	61,27460317	0,008333333	0,064447531
Italy	2	101,4722222	0,00877193	0,067572447
Finland	2	0	0,007751938	0,029403675
Turkey	2	7,419047619	0,0078125	0,03390226
Sweden	2	18,81190476	0,007936508	0,045454397
Belgium	2	1,35	0,007518797	0,02287154
Slovenia	2	8,030952381	0,007751938	0,034200842
Greece	2	0	0,007751938	0,029403675
Switzerland	2	29	0,0078125	0,036259866
France	3	31,95714286	0,007692308	0,030714077
Japan	4	0	0,006369427	0,008398065
India	5	0,866666667	0,007246377	0,01598913
Iran	6	42,5	0,006711409	0,036289863
Lithuania	6	13,5	0,006666667	0,027733961
Vietnam	6	0	0,005617978	0,010714731
Iraq	6	0	0,005649718	0,016608198
Netherlands	7	0	0,007352941	0,018964344
Austria	8	1,266666667	0,007633588	0,022893285
New zealand	9	0	0,006711409	0,008310889
Chile	10	0	0,006756757	0,00806372
Czech republic	11	0	0,007462687	0,018985327
Denmark	12	0	0,006802721	0,016020858
Estonia	12	0	0,006802721	0,016020858
Pakistan	13	0	0,006493506	0,008234413
Argentina	14	0	0,000976563	0,03030303
Uruguay	14	0	0,000976563	0,03030303
Cameroon	15	0	0,006289308	0,008896616
Algeria	16	0	0,006896552	0,011999848

According to Table 4.5, Australia, Italy, and Germany have the highest betweenness centrality, meaning that they have a strong influence on the network by them connecting the domain and distributing the information to the network. 16 of the countries have 0 betweenness centrality, meaning they are the exterior nodes and endpoints of the network. It does not mean they do not have information to distribute, it just indicates they are peripheral to the domain.

In terms of closeness centrality, the higher closeness centrality indicates a closer position to other nodes since it is the inverse of the sum of distances of nodes to each other. Italy, Spain, and the USA have the highest closeness centrality, which implies they are centrally positioned in the domain and have closer connections with the overall network.

4.4. Integrative Literature Review

Literature reviews are conducted to give a theoretical foundation for the area of research and identify crucial variables and important or key phrases that will be utilized in a research or article production. With the use of research papers, literature reviews offer a summary of the most recent evidence for practice to help readers obtain new insights and substantiate claims and views made in manuscripts (Baker, 2016). Elsbach & Van Knippenberg claims that integrative literature reviews are one of the most effective tools for expanding research and understanding in a given field. They suggest while integrative literature reviews are firmly grounded in a typical depiction of a discipline, they also provide fresh insights through a rigorous examination and synthesis of the literature in that field (Elsbach & Van Knippenberg, 2020). The integrative literature review technique is chosen and carried out in this study among the many techniques for evaluating the literature, and it is classified using the results of bibliometric analysis methodologies.

While conducting the integrating literature review in this study, the article of Richard J. Torraco has been used as a guideline. In the article, it is discussed that the integrative review of the literature is a special type of study that builds on previously published research to provide new information. Torraco identifies the essential elements of the integrative literature review, and summarizes instructions for structuring and writing integrative literature reviews as an update and expansion of a previously published article on the subject (Torraco, 2016). Clark's paper is a high-cited example of an integrative literature review, which is about the terms and descriptions of content strategy in the academic and professional literature (Clark, 2016). Minatogawa's paper is another example of an integrative review that aims to develop an

integrated framework that includes impact factors for business model innovation and characterize them (Minatogawa et al., 2018).

As Torraco suggested, an integrative literature review is useful for assembling individual works of literature and evaluating them to pinpoint the insights and perspectives they provide but also the shortcomings, exclusions, imprecision, and other issues that are ineluctable with recently published literature on a new concept. Artificial intelligence in project management is a perfect candidate as an emerging concept and the ideal strategy for this study was to do an integrative literature analysis because not only the concept is new, but the project management and artificial intelligence topics also have been studied across many disciplines, including construction management, software development, business analytics and so on, which requires an integrative study.

5. POLICY IMPLICATIONS

AI is viewed by most as an extraordinary groundbreaking technology with the capability to reshape society, driven by technological advancements and public involvement. Project managers are among the roles that AI has reshaped. However, there is currently little empirical guidance available to project managers on how to set up and implement AI in their profession (Brock & von Wangenheim, 2019). The findings of this study provide guidance and summarize the findings of studies in the literature from this perspective.

5.1. Implications on Managers

In literature, researchers are in consensus that AI will be an integrated phase of future project management practice. Brock & von Wangenheim anticipate that, for at least a while," AI and people will cooperate rather than compete with or displace one another in the future." It is also predicted that in the future, customers will pay more for individualized, human solutions rather than services facilitated by AI technology. This is known as the "human premium." In addition, rather than being a choice, most of the AI solutions in place need human intervention to some point. The study of Buah is an example of it, in the study, it is stated that, amidst the proposed interaction and collaboration agent's advantages, its primary drawback is that it still lacks human interaction when interacting with human beings. Although Buah's agent is a communicative agent that speaks and acts like a human, it is stated that it can never completely substitute the human element in conventional engagement strategies. Ergo, Buah advised that the proposed method not be seen as a substitute but rather as an addition to the conventional approach (Buah et al., 2020). Another example of AI-assisted PM is Costantino's work, which suggests a cutting-edge methodology to assist managers in evaluating projects during the evaluation process (Costantino et al., 2015).

5.2. Implications on Business

The findings of studies suggest that AI is similar to previous technologies that businesses use and adapt in many respects. Niederman suggests that, as project managers become more comfortable with AI and analytics technologies, the traditional project management issues of stakeholder interactions, risk, estimating, benefit realization, and

execution control is likely to be given another look (Niederman, 2021). Cost, time, efficiency, the satisfaction of customers, precision in decision-making, and forecasting are the main economic drivers for AI adoption while there are also important social drivers for AI adoption, sustainability, and well-being as an example. However, there are certain barriers to the adoption of AI by businesses. There are financial (cost, support, infrastructural facilities) and technical challenges, as well as there are socioeconomic factors such as reliance on non-humans, job security, insufficient knowledge, safeness, trust, and an absence of various stakeholders' perceptions (Cubric, 2020b). In addition, there is a lot of confusion about how AI will transform project management or any process that is related. Organizations must change how they approach AI and recognize that, while it is not the ultimate objective, AI offers a cluster of potent tools for digitalization, much like big data and analytics have combined becoming a method for transforming massive data volumes into groundbreaking insights (Pickup, 2019).

As thematic evolution analysis indicated, there is a tendency to improve traditional methods with AI and Machine Learning. However, while implementing AI in project management, there are also ethical questions in place. Tambe discussed some of the crucial lessons discovered when a team of personal assistant agents (Electric Elves) was deployed effectively in an office setting. The Electric Elves project produced several significant findings about social norms, privacy, and adaptable autonomy for agents deployed in office settings, such as AI should follow social norms and respect personal space (Tambe et al., 2008). To benefit AI ethically, businesses should carefully employ it in terms of ethics and social norms.

To sum up, AI is not likely to replace human-driven project management, however, there is great room for collaboration. Managers should educate themselves and the staff to embrace it and its potential improvements.

5.3. Implications on Turkey

Management of economy and development in a continuous and structured manner in Turkey has started with the development plans. The first development plan is enacted in 1963, which aims to solve issues regarding the economy, health, education, transportation, social security and justice. Development plans determine the policy to be implemented in the public sector. Large-scale government projects which are led by these development plans have played a significant role in the development of project management techniques in Turkey. Until the late 20th century the importance of Project Management was not fully understood and projects

(most of them led by the government) did not include a detailed planning and management system specific to the project. (Okumuş, 2018) From the 1980s onwards, with the start of investments in the private sector, the importance and necessity of Project Management increased and this trend is also reflected in development plans. In the 11th Development Plan, it is stated that "training for project managers will be created tailored according to their needs" (Government of Turkey, 2019)

To follow global trends in project management, Turkey made a significant effort. In 1997 İstanbul Project Management Association and following that, PMI Turkey had been established in 2007. Pre-accession process of Turkey into the European Union is also a major factor in that effort. Beginning with the Sixth Framework Programme, which is the main scientific funding programme of the EU, Turkey has participated in EU Framework Programmes. Turkey also participates in Erasmus Programme. As a result of participating in such initiatives, a pool of beneficiaries was created on both national and local levels, and several civil society groups actively carried out projects using the monies made available. (Esen & Yıldız, 2020)

Although project management culture is paving its way through different channels and still has a long way before it, AI-empowered Project Management is still a new concept for Turkey. Currently, during this study, such an initiative is absent in the literature. However, considering the current pattern, there is great potential since the importance of PM is a well-known and widely studied issue.

According to PMI Talent Gap Report, by 2030, the world economy will require 25 million additional project managers. To fill the talent shortage, 2.3 million people will need to enroll annually as project managers to meet demands. (PMI, 2021) According to the Turkey Statistical Institute, while the total population of Turkey was 84.68 million by the end of 2021, the young population in the age group of 0-14 was 18.9 million, which constitutes 22% of the total population. With its young population, Turkey is a great candidate to fill this gap. To close this gap properly, a suitable education shall be provided starting from the earlier steps of education, and the young population should be equipped with digital skills to meet novel requirements of project management.

6. CONCLUSION

This study is conducted to explore the project management domain from an AI perspective. The contribution of the study is as follows;

Firstly, in this study, the background, current situation, and future of the project management profession are explored. To do so, the domain is reviewed with a novel technique; the integrative literature review technique. The literature is divided into four groups, which are determined by co-word analysis. The themes' progress and their relevance to the literature are calculated with Callon's centrality and density. The findings of integrative literature review analysis also matched the findings of bibliographic coupling analysis and co-citation analysis. Key points have been raised during the analysis, and trends, central papers, and authors in the domain have been pointed out, which might be valuable for future research. According to the co-word analysis, "Project Management" and "Learning Systems" are the basic themes of the domain in this study while "construction" is the motor theme of the domain. "Management" is an emerging or declining theme, and the key point that determines whether a paper is emerging or declining is the keyword associated with the papers inside the cluster, including "design", "innovation management", "productivity" and "technology management. "Optimization" and "algorithms" are the niche themes for the domain.

Secondly, a comprehensive bibliometric analysis of the domain has been conducted. Bibliometric analysis is conducted under three sections, bibliometric performance analysis, network analysis, and science mapping. In performance analysis, a general overview supplemented with quantitative metrics, namely publication-related metrics and citation-related metrics is presented. The project management domain in terms of AI is visualized and categorized, and the literature is analyzed with various tools of bibliometric analysis. In network analysis, complementary methodologies and metrics that are used to enrich bibliometric analysis are provided. In addition, clustering methods, namely Louvain Method and Girvan-Newman algorithm are used to group heterogeneous data into connected subsets, and with the tools of bibliometrix, the study is visualized. In the science mapping section of the bibliometric analysis, the domain is analyzed with bibliographic coupling, co-citation analysis, co-word analysis, and co-authorship analysis methods. In bibliographic coupling analysis, keywords are analyzed regarding their impact and centrality, as well as a coupling thematic map is depicted. In co-citation analysis, 14 different key themes of the area are mapped with the key papers of

the theme. In co-word analysis, the most relevant keywords, which are proven to be consistent with the prior analysis are examined, and lastly, in co-authorship analysis, a scientific collaboration network has been depicted and the linkages between authors and countries through authors are analyzed.

Thirdly, the possible evolution of the domain has been mapped with bibliometric analysis in this study. Using the findings of performance analysis and science mapping, thematic evolution analysis is conducted in this study for project management in the era of AI between 1987 to 2022.

The findings demonstrated that AI will become an integral element of future project management practice and will have an immediate impact on the project management profession. AI will have a significant impact on cost, scheduling, and risk management, according to the literature. As key researchers in the domain (Fridgeirsson et al., 2021; Ong & Uddin, 2020) pointed out, project management as a profession is a promising concept in the scientific field. While data science, AI, and PM become more integrated, it is expected that they will interact more to develop more effective project management procedures. Its progress will be substantially aided by research in this developing sector. Identifying this concept from an AI perspective is necessary, yet there is still a lot more room for improvement.

Another point fact that has been observed in this study is that the project management term has changed a lot and will keep changing in the future. It originated from construction management, however, now it has a broader meaning, which also includes construction management as well. However, digitalization has its immense effects on the domain and since a vast amount of projects are either software projects or software-oriented projects, the term itself is now used interchangeably with software project management. Project management in literature is defined as a framework that utilizes decision support systems, planning, different levels of management and human resources while also defining project management as a profession on its own.

From the national perspective, Turkey has shown improvement in terms of Project Management, especially in the last decade. However, there is still a gap and lack of interest in the academic world for project management. As statistics suggest, there is great potential in the domain and Turkey is a good candidate to fill the global need for project management, with its young population and adaptive strategic planning tools.

Due to the aim of the study, this study is limited by the effects of Artificial Intelligence on Project Management only. However, many different factors affect the evolution of PM which can be a good subject to study. For example, while AI is automatizing the routine work of PM, emotional factors gain more and more importance. The effect of emotional intelligence on project management can be a good study for the domain. Another limitation is the database, the study is limited to WoS and Scopus databases only. If metadata usable by package programs will be available from other databases, the study can be extended further with these new datasets.

For further study, a case study backed by surveys can be conducted, either on the national or regional level. The study proposed that AI will have an immediate effect on PM, however the domain itself is magnitudinous and it is worth exploring in which sectors PM will be effected at which level of severity, also it is worth elaborating more on these effects. In addition, an SME perspective to the study can give various insights into the domain and take it further.

To sum up, based on 500+ articles, by providing a roadmap and an integrative literature review, this study is an attempt of summarizing the history of PM and painting a picture of the future of AI-augmented Project Management with novel methodologies. The revolution by AI is inevitable, yet in the PM domain, it is shown that it would be more creative than destructive.

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Robot Resource Management . Situation-Action Model for Project Contex- tualization As part of Project (Management) Life Cycle , The Situational Leadership Model (Hersey and Blanchard , 1977) is also one of the most useful and.

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8. APPENDIX

APPENDIX-1. Bibliographic Coupling Results

label	group	freq	Callon's centrality	Impact (Normalized Global Citation Score)
support vector machine	1	69	0,258538088	2,844879845
ant colony optimization	2	43	0,419872904	1,973004676
decision support system	3	18	0,261297356	1,752424599
support vector machine	4	24	0,414329619	1,932515669
alternative distributed problem-solving	5	24	0,248609487	2,305223558
machine learning algorithms	6	12	0,33137144	3,285407068
active learning exercise	7	5	0,310559006	0
artificial intelligence assist	8	4	0,32038446	2,383316783
Resource-constrained project scheduling	10	16	0,225232596	2,476455035
cooperative expert systems	11	4	0,310559006	1,565217391
classifying construction contractors	13	7	0,369040305	3,427145709
concurrent product development	14	4	0,170246928	2,80139381
artificial neural network	18	64	0,313106088	4,010279065
active inference applicability	19	17	0,300969991	2,157866357

APPENDIX-2. Node Degrees

Cluster	Color Code	Node	Betweenness Centrality (BC)	Closeness Centrality (CC)	PageRank
1	Red	zadeh l.a. 1965	118,1013707	0,000179179	0,017540018
1	Red	goldberg d.e. 1989	0	0,000174795	0,008750623
1	Red	holland j.h. 1975	99,42277992	0,000178859	0,016832874
1	Red	klir g.j. 1995	0,857142857	0,000175562	0,011362535
1	Red	gen m. 1997	0,375	0,000175408	0,010203722
1	Red	haykin s. 1999-1	0	0,00017618	0,010696916
1	Red	barraza g.a. 2000	0	0,000174795	0,008750623
1	Red	ko c.h. 2002	0	0,000175408	0,010219876
1	Red	michalewicz z. 1996	1,566486486	0,000176025	0,010048836
1	Red	russell j.s. 1997	0	0,000175408	0,010219876
1	Red	cheng m.y. 2003	0	0,00017618	0,010696916
1	Red	liu l. 2007	0	0,000178476	0,008611229
1	Red	maier h.r. 2000	0	0,00017618	0,010696916
2	Blue	breiman l. 1996	0	0,000171028	0,008594313
2	Blue	vandevoorde s. 2006	60,76380952	0,000174307	0,017417926
2	Blue	vanhoucke m. 2007	20,49	0,000174004	0,01387095
2	Blue	cheng m.-y. 2010-1	6,68	0,000173551	0,012183356
2	Blue	cortes c. 1995	28,72619048	0,000172801	0,014040827
2	Blue	elshaer r. 2013	20,49	0,000174004	0,013869008
2	Blue	vanhoucke m. 2011	20,49	0,000174004	0,013869008
2	Blue	abourizk s. 1994	6,68	0,000173551	0,012183356
2	Blue	demeulemeester e. 2003	6,68	0,000173551	0,012183356
2	Blue	fleming q. 2005	0	0,000172503	0,010504564
2	Blue	lipke w. 2009	0	0,000171174	0,008767511
2	Blue	vanhoucke m. 2012	0	0,000172503	0,010475015
2	Blue	vanhoucke m. 2010	0	0,000172503	0,010504564
2	Blue	bowman r.a. 2006	0	0,000171321	0,009294181
2	Blue	cheng m.-y. 2010-2	0	0,000172503	0,010475015
2	Blue	colin j. 2014	0	0,000172503	0,010653841
2	Blue	fazar w. 1959	0	0,000172503	0,010653841
2	Blue	jolliffe i. 2005	0	0,000172503	0,010653841
2	Blue	kelley j. 1959	0	0,000172503	0,010653841
2	Blue	lipke w. 2003-1	0	0,000172503	0,010653841
2	Blue	lipke w. 2003-2	0	0,000170736	0,008310154
2	Blue	pearson k. 1901	0	0,000172503	0,010653841
2	Blue	raz t. 2000	0	0,000171321	0,009294181
2	Blue	uyttewael e. 2005	0	0,000172503	0,010475015
2	Blue	vapnik v. 2000	0	0,000169291	0,008418061
2	Blue	wauters m. 2014	0	0,000172503	0,010653841

3	Dark Green	boehm b.w. 1984	3,5	0,000133404	0,014587166
3	Dark Green	jorgensen m. 2007	0	0,000133138	0,009087677
3	Dark Green	park h. 2008	0,5	0,000133316	0,011950323
3	Dark Green	huang x. 2007	0	0,000133227	0,010103455
3	Dark Green	shukla k.k. 2000	0	0,000133227	0,010103455
4	Purple	hegazy t. 1998	35,8	0,000178923	0,01144366
4	Purple	adeli h. 1998	35,8	0,000178923	0,01144366
4	Purple	williams t.p. 1994	0	0,000177715	0,011309529
4	Purple	serpell a.f. 2004	0	0,000177715	0,011314749
4	Purple	singh s. 1990	0	0,000177715	0,011309529
4	Purple	wilmot c.g. 2005	106,0772201	0,000179308	0,011799076
4	Purple	yau n.j. 1998	0	0,000177715	0,011314749
4	Purple	an s.h. 2007	0	0,000177715	0,011309529
4	Purple	arditi d. 1991	0	0,000177715	0,011309529
4	Purple	bowen p.a.	0	0,000177715	0,011309529
4	Purple	khosrowshahi f. 1996	0	0,000177715	0,011309529
4	Purple	kim g.h. 2005	0	0,000177715	0,011309529
4	Purple	mohamed a. 1998	0	0,000177715	0,011309529
4	Purple	practice and 1985	0	0,000177715	0,011309529
4	Purple	yu w.d. 2006	0	0,000177715	0,011309529
5	Dark Orange	khosrowshahi f. 2007	0	0,000129066	0,011349629
5	Dark Orange	hwee n.g. 2002	0	0,000129066	0,011349629
6	Brown	kohavi r. 1995	0	0,000134644	0,009575157
6	Brown	arditi d. 1998-1	0	0,000134735	0,010573793
6	Brown	arditi d. 2010	2,5	0,000134916	0,013564762
6	Brown	arditi d. 2005	2,5	0,000134916	0,013564762
6	Brown	chen j.-h. 2007	0	0,000134735	0,010573793
6	Brown	pulket t. 2009	0	0,000134644	0,009575157
7	Magenta	ng s.t. 1999	5	0,000136091	0,011805794
7	Magenta	nguyen v.u. 1985	0	0,000135999	0,010517263
7	Magenta	hatush z. 1997	0	0,000135999	0,010517263
7	Magenta	holt g.d. 1994	12	0,00013637	0,015766171
7	Magenta	khosrowshahi f. 1999	0	0,000135999	0,010517263
7	Magenta	russell j.s. 1988	0	0,000135999	0,010517263
7	Magenta	topcu y.i. 2004	0	0,00013563	0,009806389
8	Grey	lecun y. 2015	0	0,000129066	0,011349629
8	Grey	deng l. 2014	0	0,000129066	0,011349629
9	Cyan	teece dj 1997	0	0,00013048	0,011349629
9	Cyan	eisenhardt km 2000	0	0,00013048	0,011349629
9	Cyan	teece dj 2007	0	0,00013048	0,011349629
10	Light Orange	assaf s.a. 2006	0	0,000129066	0,011349629

10	Light Orange	odeh a.m. 2002	0	0,000129066	0,011349629
11	Parliament	bilal m 2016	0	0,000129066	0,011349629
11	Parliament	hosseini mr 2018	0	0,000129066	0,011349629
12	Pink	cha yj 2017	0	0,000129066	0,011349629
12	Pink	salehi h 2018	0	0,000129066	0,011349629
13	Green	hartmann s. 1998	0	0,000129066	0,011349629
13	Green	kolisch r. 1996	0	0,000129066	0,011349629
14	Yellow	wamba sf 2017	0	0,000129066	0,011349629
14	Yellow	wernerfelt b 1984	0	0,000129066	0,011349629

APPENDIX-3. Thematic Evolution Data

From	To	WII	II	O	SI
artificial intelligence--1987-1999	algorithms--2000-2009	0,10	0,04	14	0,02
artificial intelligence--1987-1999	decision support systems--2000-2009	0,08	0,04	12	0,01
artificial intelligence--1987-1999	expert systems--2000-2009	0,47	0,25	20	0,03
artificial intelligence--1987-1999	project management--2000-2009	0,60	0,04	75	0,01
computer science--1987-1999	project management--2000-2009	0,60	0,50	3	0,01
decision making--1987-1999	decision support systems--2000-2009	0,53	0,08	7	0,02
decision making--1987-1999	expert systems--2000-2009	0,12	0,25	2	0,06
distributed computer systems--1987-1999	decision support systems--2000-2009	0,40	0,20	3	0,02
distributed computer systems--1987-1999	distributed computer systems--2000-2009	0,50	0,50	4	0,17
information technology--1987-1999	learning systems--2000-2009	0,22	0,06	6	0,03
information technology--1987-1999	project management--2000-2009	0,28	0,06	5	0,01
neural networks--1987-1999	project management--2000-2009	1,00	1,00	6	0,01
planning--1987-1999	decision support systems--2000-2009	0,31	0,10	8	0,02
planning--1987-1999	learning systems--2000-2009	0,05	0,10	2	0,04
planning--1987-1999	project management--2000-2009	0,28	0,10	4	0,01
problem solving--1987-1999	decision support systems--2000-2009	0,35	0,17	7	0,02
problem solving--1987-1999	learning systems--2000-2009	0,10	0,17	2	0,05
strategic planning--1987-1999	algorithms--2000-2009	0,09	0,07	4	0,02
strategic planning--1987-1999	decision support systems--2000-2009	0,05	0,07	3	0,02
strategic planning--1987-1999	distributed computer systems--2000-2009	0,50	0,50	2	0,07
strategic planning--1987-1999	project management--2000-2009	0,30	0,07	9	0,01
systems engineering--1987-1999	algorithms--2000-2009	0,43	0,50	3	0,03
systems engineering--1987-1999	learning algorithms--2000-2009	0,29	0,50	4	0,11
algorithms--2000-2009	construction industry--2010-2022	0,14	0,03	9	0,01
algorithms--2000-2009	decision support system--2010-2022	0,06	0,03	7	0,01
algorithms--2000-2009	learning systems--2010-2022	0,22	0,03	12	0,01
algorithms--2000-2009	management--2010-2022	0,02	0,03	3	0,01
algorithms--2000-2009	scheduling--2010-2022	0,02	0,04	2	0,02
decision support systems--2000-2009	construction industry--2010-2022	0,07	0,02	4	0,01
decision support systems--2000-2009	decision support system--2010-2022	0,06	0,03	7	0,01
decision support systems--2000-2009	learning systems--2010-2022	0,03	0,02	3	0,01

decision support systems--2000-2009	management--2010-2022	0,02	0,02	4	0,01
decision support systems--2000-2009	project management--2010-2022	0,55	0,02	28	0,01
decision support systems--2000-2009	scheduling--2010-2022	0,02	0,04	2	0,01
expert systems--2000-2009	project management--2010-2022	0,47	0,25	8	0,01
learning algorithms--2000-2009	learning systems--2010-2022	0,16	0,13	3	0,01
learning algorithms--2000-2009	project management--2010-2022	0,26	0,13	3	0,01
learning systems--2000-2009	construction industry--2010-2022	0,10	0,06	7	0,01
learning systems--2000-2009	decision support system--2010-2022	0,07	0,06	5	0,02
learning systems--2000-2009	learning systems--2010-2022	0,31	0,06	10	0,01
learning systems--2000-2009	management--2010-2022	0,08	0,06	4	0,01
learning systems--2000-2009	project management--2010-2022	0,21	0,06	7	0,01
project management--2000-2009	budget control--2010-2022	0,04	0,06	2	0,01
project management--2000-2009	construction industry--2010-2022	0,13	0,01	18	0,01
project management--2000-2009	decision support system--2010-2022	0,02	0,03	5	0,01
project management--2000-2009	learning systems--2010-2022	0,06	0,01	12	0,01
project management--2000-2009	management--2010-2022	0,01	0,01	3	0,01
project management--2000-2009	project management--2010-2022	0,49	0,01	97	0,00

WII: (Weighted Inclusion Index), II: (Inclusion Index), O: Occurrences, SI: Stability Index