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DOI
10.1061/(ASCE)CO.1943-7862.0002168

Publication date
2021

Document Version
Final published version

Published in
Journal of Construction Engineering and Management

Breakdown of Engineering Projects' Success Criteria

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Abstract: This paper presents the findings from a study of the breakdown of project success criteria. An exploration of the evolution of studies on the success of engineering projects over decades was the basis for a project success definition proposal. Using a comprehensive literature review of success criteria for engineering projects, a list of 133 different success criteria was identified. Those criteria were analyzed to develop an integrated framework of project success criteria, describing its hierarchical decomposition. Such a breakdown structure could serve as a starting point when setting project success criteria for a specific project, because the importance of criteria will be context dependent. Practitioners or stakeholders could discuss and tailor it based on specific features of engineering projects or specific needs and interests. Generally, criteria have evolved from simple work-related factors to focusing more on the complex benefits of the projects. Such an evolving success definition has implications for further studies of project success and might contribute toward a long-term vision in which all projects will be delivered successfully. **DOI: 10.1061/(ASCE)CO.1943-7862.0002168.** *© 2021 American Society of Civil Engineers.*

Author keywords: Engineering projects; Success; Success criteria; Breakdown.

Introduction

There have never been so many live projects as there are in today's modern world (IPMA 2019; PMI 2017). Projects are witnesses and instruments of the human needs for change and development. They respond to ideas, needs, or problems, serving as tools for transformation. Although high projectification (Schoper et al. 2018)—shown as a number or as a percentage—confirms the development policy and dynamics of a company, organization, or community, it does not guarantee a better tomorrow per se. We do not simply need many projects; rather, we need many successful projects. The word success has become a key word in the project business and for project practitioners over the last decades.

Although each project by itself is an instrument of change, there is a huge and permanent current of changes in parallel within each project. Therefore, the project management profession increasingly is exposed on both sides: to the expectations of stakeholders, and to the flood of changes. As expectations of benefits steadily rise, scopes become more complex and stakeholders become more demanding, so the project manager's job becomes more and more stressful. Whatever is achieved or delivered today will be challenged tomorrow (McKinsey & Company 2019)—by the bigger-better-faster rule—so the great success delivered yesterday, if repeated tomorrow, could turn into average performance or even failure. Managers, engineers, and all kind of experts prove their competences and capacities by delivering according to the criteria laid down by specifications and expectations; they are expected to deliver an outcome at least slightly better than agreed, and certainly better than their predecessors provided.

Projects mean working with people and for people (Huemann 2015). Understanding people and their needs, problems, interests, values and cultures, standards, organization and governance, requirements, and objectives is at the heart of the management of a project. In the end, people will declare it a success or failure. Despite looking manageable and being covered by many tools and techniques, dealing with people is far from an easy job.

Stakeholders are the key engine for each project (Derakhshan et al. 2019), but many of them are characterized as sunflowers, always oriented to the sun—that is, seeking benefits for themselves. This is not abnormal; it is fair if such goals exist within a multiple-win scenario, encompassing compromise and some benefits for all involved, according to their contribution to its success.

Nevertheless, after a project is over, a number of questions remain. Was it all worth it? Did the project fulfill its planned aims? Did it satisfy stakeholders? Did it bring benefits to the owner and investors and make users happy? How can this be measured and proved? Moreover, if it failed at some points or in some aspects, can it, nevertheless, still be perceived as successful? What was done wrong, and when and why? What was learned for the future?

Project success is an evergreen topic which will never stop attracting the attention of researchers and practitioners. This is logical: on the one hand, success is at the heart of launching each project, along with overall expectations and participation. On the other hand, everything achieved in defining or contributing to project success is satisfactory only for a certain period, after which boundaries shift and new research and practices are sought. Many references testify to the continuing interest in this topic. In the early stages of modern project management, papers were published with a particular focus on money, time, and quality as key success criteria (Oisen 1971). However, researchers soon began to explore much more complex criteria than the so-called iron triangle (Morris and Hough 1987; Pinto and Prescott 1990; Packendorff 1995; Turner 1999). Over the course of several decades, a number of more complex views and different ideas about how to evaluate the success of the project have been presented (Atkinson 1999; Chan 2001; Cooke-Davies 2002;

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Note. This manuscript was submitted on January 30, 2021; approved on June 23, 2021; published online on August 26, 2021. Discussion period open until January 26, 2022; separate discussions must be submitted for individual papers. This paper is part of the ***Journal of Construction Engineering and Management***, © ASCE, ISSN 0733-9364.

Hughes et al. 2004; Shenhar and Dvir 2007; Din et al. 2011; Cheng et al. 2013; Lindhard and Larsen 2016; Albert et al. 2017). Recent research confirmed the importance of the topic as evergreen, but also focused research on specific parts of this complex topic that make a significant contribution to the totality (Meredith and Zwikael 2019; He et al. 2019; Joslin and Müller 2016; Wu et al. 2021). The researchers agreed that the main keywords that unite the interest of practitioners and researchers in relation with project success are related to its criteria and factors, i.e., its management that delivers success. Moreover, despite all the research to date, the topic of project success criteria has not been concluded and it remains open to future research, because expectations and needs of project stakeholders are changing constantly and becoming more demanding (McKinsey & Company 2019), and perspectives of different project stakeholders on relevant project success criteria will vary (Koops et al. 2016). Although tools such as project definition rating index (PDRI) are available to assess projects in terms of the effort spent in the front-end phase of projects (ElZomor et al. 2018), there still is no agreement in the literature about how to evaluate project success (Frefer et al. 2018), and existing project success evaluation models suffer from their inapplicability to all project types (Meredith and Zwikael 2019).

This paper defined a framework for expanding the scientific debate, focused on the main research questions

- What is project success?
- How does it stand in regarding engineering projects?
- How was it presented in the research papers over decades?
- What are the available criteria for measuring it?
- What could be its decomposition and recomposition while dealing with engineering projects?

To investigate the answers to these questions, first, a comprehensive literature review was performed to identify how the definition of engineering project success and engineering project management success evolved over the last decades. This review resulted in a proposed definition of project success based on the integration of previous research findings. Next, a systematic literature review was performed to identify and categorize all 133 project success criteria with the assistance of expert focus groups from water infrastructure and transport engineering projects. This resulted in a proposal for a generic success criteria breakdown structure, which could serve as an initial step when dealing with the topic in engineering management practice. Finally, the main findings, limitations, and conclusions of the study were presented. There have been many attempts to define project success, but without integration of research findings over time and across the line of cognition both to create guidance and to allow tailoring for different project environments, organizations, and sectors, which was the aim of this study.

The contributions of this study cover project management theory and practice. The first contribution is a systematic literature review of the fields of engineering project success and criteria for success, resulting in a proposal of a consolidated definition of project success and an extensive list of success criteria for engineering projects. The second contribution is the proposed project success criteria breakdown structure, which can be used by project practitioners to refine their success definition in their projects. The proposed approach is flexible and includes the possibility of tailoring, so different clusters of criteria may be tested in different environments to create bespoke success models. Finally, we discussed the evolution of the success criteria over the decades and suggested a strategic framework for future studies, giving clear and simple guidance for success model creation and deeper understanding of project success layers.

Project Success and Project Management

Despite decades of studies of project success, project management success, success measures, success criteria, and success factors, researchers still have not agreed upon what makes a project successful (Albert et al. 2017), what constitutes projects success (Frefer et al. 2018), and how to plan and deliver a successful project (Meredith and Zwikael 2019). Furthermore, owners and investors still cannot have guarantees for achieving expected benefits and for creating a project package that leads to successful delivery. On the one hand, it is logical that we cannot have a 100%-reliable prediction or guarantee of success, due to overcomplexity driven by stochastic and dynamic parameters. In addition, it is not possible for all projects to achieve success, due to their large number and the many factors which affect them. The open question for the research agendas, however, is how far frontiers can be pushed toward "the vision where all projects are successful" (IPMA 2014), i.e., how can we program for success?

From the project management perspective, the big picture is rather simple. Researchers observe criteria as measures for success, and factors as enablers of and contributors to success (Jari and Bhangale 2013). Criteria are very important, because once they are defined and set, they direct a project management team and strongly influence all decisions in a project. At first glance, dealing with criteria may seem very simple, as a simple define and check fulfillment after realization. However, even a simple breakdown raises questions related to success criteria, such as how can we set the right criteria? At which point should we measure them? How will we measure them? How can we be sure that we set appropriate and measurable criteria? How do criteria change over the time? How can we measure criteria interaction, in which some criteria influence others, and some of our desirable scenarios are reverse-related? Can we apply criteria in different contexts? This is an ongoing debate, and this article provides a contribution to this discussion.

Projects such as the Sydney Opera House or the Millennium Dome have taught us that we cannot apply only simple criteria such as time, cost, and quality to projects. For example, the Sydney Opera House was planned to be built in 5 years, with a budget of AUD 7 million, but in reality the construction took 10 years more and costs were nearly 15 times higher than anticipated (Flyvbjerg et al. 2009). However, would anyone now say that the building that became a symbol of a whole continent and a part of UNESCO's inheritance is a failure? On the other hand, the Millennium Dome in London, a so-called white elephant, was built on time and within the budget of nearly ₤600 million (Bourne 2007). However, it was left without end users after the millennium celebration had been held, and its main purpose then had to be replanned. Both cases illustrate that simply applying the success criteria from the past (such as only cost and time) can be challenged easily.

To understand project success criteria, it is important to understand how thinking on project success has evolved. We conducted comprehensive desk research of project success studies over time until 2017. We registered and sorted the key findings by decades (Table 1).

The project success studies were divided into five key phases, one per decade (Table 1). The early phase, before the 1980s, focused on the so-called iron triangle as a success model, in which cost, time, and quality were the dominant targets. Due to its simplicity, measurability, and practicability, this became a very popular criterion. However, focusing on isolated elements without insights into correlation and context was a serious weakness and it was a reason for moving forward. In the 1980–1990 decade, researchers made a distinction between project success and project management success, in which the iron triangle was retained for measuring project

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Table 1. Engineering project success in recent decades

Key observations	Dominant criteria	Examples
	Pre-1980	
The period is known for the development of the first project success model: the so-called iron triangle, represented by three main project success measures: time (project is completed within the planned deadline), budget/money (project is completed within the planned budget), and quality (project is delivered with prescribed quality specifications). The iron triangle was the pre-eminent way to measure project success because it provides comparison between planned and actual state in an easy way. The inexorable objectivity of the iron triangle, its simplicity, its recognition, and its measurability ensured its great popularity through history. However, its unyielding nature and straightforward insight into three main project constraints (deadline, budget, and quality) was challenged regularly because correlation among those three factors was not focused, despite known dependencies.	Time budget/money quality	Oisen (1971)
	1980–1990	
Many studies continue to include the iron triangle in their success models, but they argued that time, cost, and quality cannot be exclusive criteria for project success. The distinction between time, cost, and quality criteria and product success criteria was made in this period, in which the first three criteria were tied to project management success, and the last was suggested for measuring project success. Therefore, a project was deemed to be successful if its delivered product or service was operating in technical and functional senses, as defined by specifications.	Technical performance Functional requirements specifications	Morris and Hough (1987), de Wit (1988), and Navarre and Schaan (1990)
	1990–2000	
A wider set of criteria was introduced in order to enrich models of this period, and diverse short-term and long-term success perspectives. In accordance, life cycle and after-delivery phase were focused, driven by owner and user opinion. Therefore, the triangle model, as a foundation, soon became a quadrangle, due to the adoption of a new criterion—client satisfaction. In addition, studies in this period used different criteria linked to client organization, such as increase of organizational effectiveness, business success in general, contribution to strategy realization, and organization preparation for the future. In addition to the influence on client organization, the project via its deliverables effects (in a direct or indirect manner) a series of changes in the wider environment: economic, social, institutional, political, technological, professional, educational, and so forth. In that sense, thinking and success models included criteria of influence on project context and environment as additional project success criteria.	Short term–long term Client satisfaction Life cycle Organization and strategy Wider project environment: economic, social, institutional, political, technological, professional, educational, and so forth.	Pinto and Prescott (1990), Freeman and Beale (1992), Packendorff (1995), Shenhar et al. (1997), Songer and Molenaar (1997), Liu and Walker (1998), Atkinson (1999), Baccarini (1999), Griffith et al. (1999), Hobday (2000), and Sadeh et al. (2000)
	2000–2010	
In parallel to the previous decade's trend, a question had been emerging about the satisfaction of all other project stakeholders, not only the client and user. Namely, each interest group applies its own measures in judging the project, so the same project could be at the same time a great success and a huge failure, depending on which stakeholder is evaluating the project outcome. With that in mind, many studies included stakeholder satisfaction in their relevant project success criteria, which moved the focus to a more subjective area and perception. Consequently, a differentiation for private and public project success criteria was recognized. On that basis, ideas of project success as a perceptive element became strong, mostly for public projects. Private projects stayed within numerical success criteria.	Stakeholders' satisfaction Public versus private Numerical and perceptive	Tukel and Rom (2001), Fincham (2002), Chan and Chan (2004), Andersen et al. (2006), Elattar (2009), Müller and Turner (2010), and Toor and Ogunlana (2010)

Table 1. (*Continued.*)

Key observations	Dominant criteria	Examples
	2010–2020	
Over the last decade projects have been observed in a larger context, due to globalization and international cooperation. Global risk reports and climate change reports have influenced the project mindset. Therefore, contribution to the community or even to society has become an important part of modern success debates. Engineering project success criteria is tied to community standards and expectations coming from megaprojects, infrastructure projects and other major projects. Many researchers focused on a balance of criteria coming from business, environmental, and societal perspectives.	Community development welfare	Müller and Jugdev (2012), Dada (2013), Jari and Bhangale (2013), and Gemünden and Schoper (2014)

management success, whereas project success was linked to the success of the product or service that was delivered by the project (Radujkovic and Sjekavica 2017). In that way, technical performance and functional requirements were linked to the triangle model. In the period 1990–2000, many researchers built on that foundation and emphasized project success in terms of short-term and long-term aspects, thus observing project life cycles in a wider context that included organizational, social, political, strategical, environmental, technological, and other aspects. Client and user satisfaction became an important part of these criteria. In the decade 2000–2010, attention was given to the distinction between public and private project success and the positions of all project stakeholders were emphasized. As subjectivism entered the criteria set, the development of numerical and perceptive elements was derived logically, and the approach was tailored in relation to the stakeholders involved. In the most recent decade, many studies have placed project success in an even wider context, in which each project, in addition to bringing benefits to those directly involved, also should contribute to the community or even to societal welfare, progress, and development (especially major projects and megaprojects). Such a trend is influenced by globalization and networking, due to the pressure of different important global reports, such as world risk reports, global climate change reports, and so forth, and consequently sustainability was recognized as a new important criterion (Silvius and Schipper 2016; Sabini et al. 2019).

Across all the decades, we noticed that each decade's studies added a new aspect to the existing overview of project success criteria. Despite critics of past success studies, we suggest observing the overall period as a continuous progression of the topic. Therefore, putting all major findings together, project success can be defined by delivery on time, on budget, and according to specifications, and in which the delivered product or service, over time, achieves defined objectives in accordance with the relevant context (organizational, social, political, strategic, environmental, technological, and so forth), and, in addition, the project contributes to the welfare, progress, and development of the community or even society at large without compromising the future.

This suggested definition confirms that success is a composite, in which the balance among elements can be tailored in alignment with the internal and external circumstances and features of each project to the key stakeholders' needs and arrangements. From our perspective, this definition fits the context of engineering projects.

Systematic Literature Review of Project Success Criteria

The findings from section "Project Success and Project Management," including the proposed project success definition, were the inspiration for obtaining deeper insight into studies of project success criteria over time. At first, criteria as a topic looks very simple, maybe even bizarre, due to a set and check mindset, and it may seem that there is not much room left for research. However, criteria are essential parameters for each activity because, after they are set, they strongly influence everything and everyone involved in or having interests in it. We carried out desk research based on selected international articles related to success criteria and engineering projects. The research was performed in the following steps (Fig. 1):

1. project success criteria identification;
2. project success criteria categorization;
3. pilot test of proposed categorization, and calculation of frequencies of project success criteria; and
4. analysis and discussion.

Project Success Criteria Identification

To find project success criteria in engineering projects, recent relevant literature was analyzed by means of a systematic review of publications between 2011 and 2017, which represented modern thinking, trends, and research results in the field. These perceptions were combined with additional sources from literature published before 2011. The reason for this combination was that most of the success criteria that were proved to be significant in the past were incorporated at some level into recent success models as well. This also matched our proposal for the definition of project success in the section "Project Success and Project Management," for which criteria have expanded over the years.

The methodology of the recent (2011–2017) literature review in the field consisted of the following steps:

1. Five search engines were searched: Academic Search Complete (EBSCO), Current Contents Connect (Web of Science), Emerald Insight, Hrčak (a local southeastern Europe engine), and Science Direct. The search was based on the combination of the keywords success criteria and engineering or construction projects in all fields, with a time filter (from January 2011), language filter (English), publication-type filter (academic journals and articles), and research branch filter (depending on the engine, engineering and project management were selected). The initial number of articles was 374.
2. All articles which did not focus on the desired research topic were deselected from the initial set during the title check, after reading the abstract, or after reading the whole article. After this, only 23 articles remained as significant for this study. The deselected waived articles mostly did not focus on project success criteria as a research objective, but rather mentioned the topic generally or marginally.

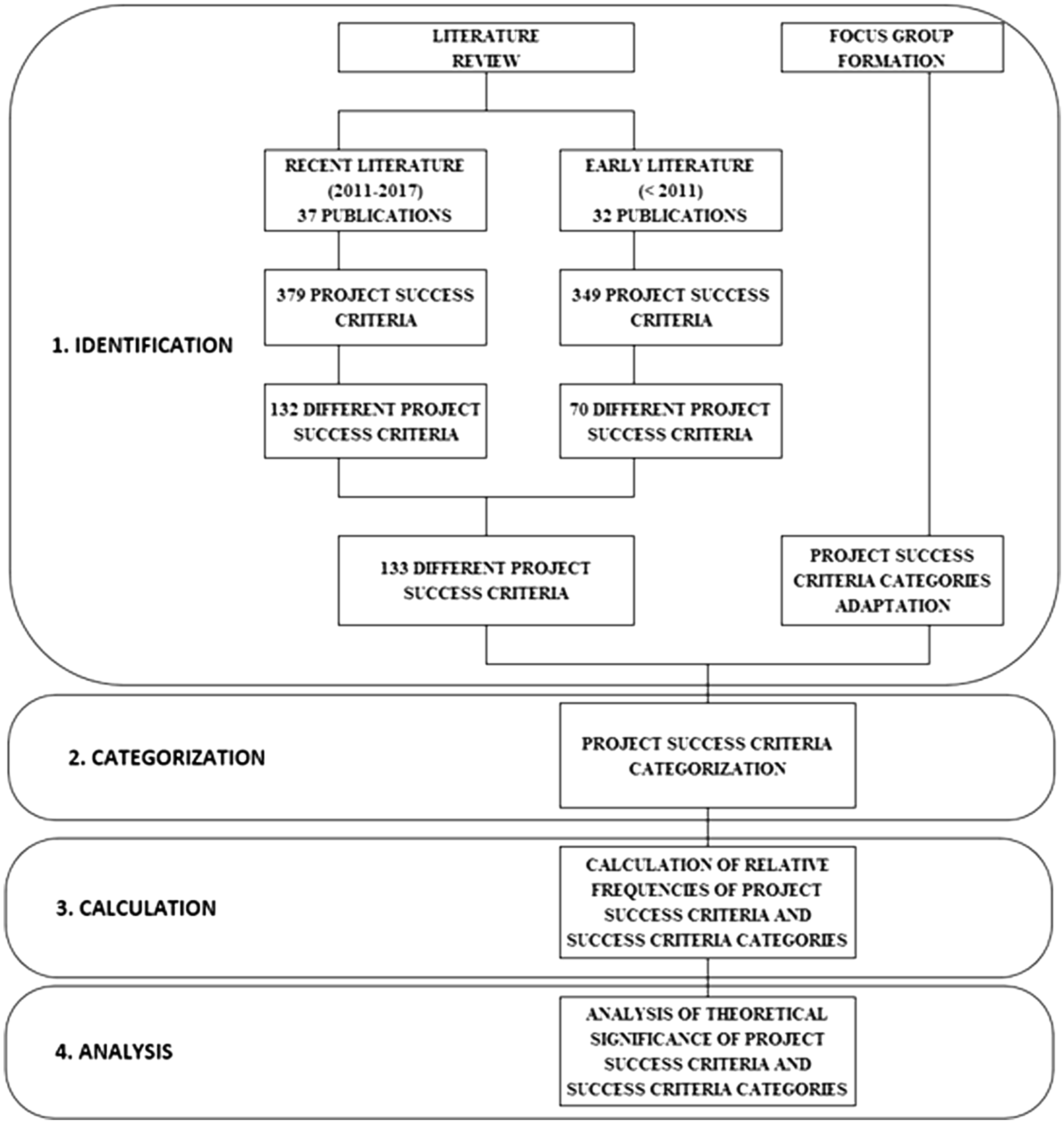

Fig. 1. Research flowchart.

3. These articles were combined with an additional 14 articles found on Google Scholar, with the same parameters regarding keywords, time span, and language, and which were evaluated by the authors as significant in answering the research question. Articles picked from Google Scholar were added in a special step due to the engine's different parameters, which resulted in an enormous, unmanageable number of articles. Articles that were highly cited based on scholar ranking and that fit the research question were added in this step. The total number of selected articles for analysis at this point was 37 (Al-Tmeemy et al. 2011; Din et al. 2011; Khosravi and Afshari 2011; Kusljic and Marenjak 2011; Adinyira et al. 2012; Anees et al. 2013; Cheng et al. 2012; Demir and Yilmaz 2012; Heravi and Ilbeigi 2012; Lee and Yu 2012; Manana et al. 2012; Tabish and Jha 2012; Aniekwu et al. 2013; Cheng et al. 2013; Dada 2013; Kerzner 2013; Ribeiro et al. 2013; Pinter and Pšunder 2013; PMI 2017; Abulnour 2014; do Rosário Bernardo 2014; Hanna et al. 2014; Howsawi et al. 2014; Ihuah et al. 2014; Iqbal et al. 2014; Liu et al. 2014; Rashvand and Zaimi Abd Majid 2014; Santos et al. 2014; Zavadskas et al. 2014; Chandra 2015; De Carvalho et al. 2015; Erdem and Ozorhon 2015; Fahri et al. 2015; Masrom et al. 2015; Lindhard and Larsen 2016; Ramlee et al. 2016; Tabassi et al. 2016).
4. From the analysis of 37 articles, a total of 379 project success criteria were identified, with multiple duplications. In total, 132 different project success criteria were found.
5. Each success criteria included a reference of author(s) and year of publication.

The methodology of the review of relevant literature published before 2011 consisted of the following steps:

1. From the comprehensive literature review in the field of project success criteria through the years, 32 publications that represented the state of the art of the topic and that could be defined as the core literature were selected (Morris and Hough 1986; de Wit 1988; Pinto and Slevin 1988; Pinto and Prescott 1990; Freeman and Beale 1992; Latham 1994; Alarcón and Serpell 1996; Shenhar et al. 1997; Songer and Molenaar 1997; Egan 1998; Liu and Walker 1998; Atkinson 1999; Baccarini 1999; Chua et al. 1999; Crane et al. 1999; Griffith et al. 1999; Lim and Mohamed 1999; Turner 1999; Chan 2001; Tukel and Rom 2001;

Cooke-Davies 2002; Takim and Akintoye 2002; White and Fortune 2002; Chan and Chan 2004; Hughes et al. 2004; Bryde and Robinson 2005; Salminen 2005; Blindenbach-Driessen and van den Ende 2006; Menches and Hanna 2006; Shenhar and Dvir 2007; Ahadzie et al. 2008; Elattar 2009).

2. After analyzing the 32 publications, a total 349 project success criteria were identified, again with multiple duplications. In total, 70 different project success criteria were identified, among which only one was new compared with the 132 criteria from the more-recent literature.
3. The findings from relevant literature from 2011 to 2017 and from before 2011 were merged by overlapping the lists criteria. A total of 133 different project success criteria were identified. Each success criteria included a reference of author(s) and year of publication.

Testing and Categorization of Project Success Criteria—Example for Water and Transport Infrastructure Projects

Project Success Criteria Categorization—Water Infrastructure Focus Group Results

After the identification of 133 different project success criteria, we performed two tests to determine how the criteria fit the practice; namely which criteria were more present in practice and whether the criteria could be categorized. For the testing, we selected water and transport infrastructure engineering projects. These were chosen due to their high presence within the engineering portfolios and their high importance for society at large, because transport systems are a fundamental part of modern and economic infrastructure (European Commission 2017). Water resources and the essential services they provide are among the keys to achieving poverty reduction, inclusive growth, public health, food security, and dignity for all and long-lasting harmony with earth's essential ecosystems (United Nations 2015). This example of water infrastructure projects was the first; key details are presented in this section.

A focus group of seven project management experts tested the categorization of the detailed breakdown. The focus group participants were experienced management experts, highly educated, with more than 10 years of working experience in managing complex water infrastructure projects within the European context. The focus group method uses experts in a field as so-called opinion makers in practice development, giving opinions, working on specific exercises or validation of priorities or opinions (Kitzinger 2005; Naglea and Williams 2013). They were presented with insights from the literature review and the overall list of the 133 identified success criteria, based on which they extracted 31 criteria category and six macrocategories, specialized for water infrastructure projects. These categories formed the first two levels of the success criteria breakdown. The third level was created by joining 133 success criteria in 31 categories, also suggested by the focus group. Due to the large amount of information, this third level is not shown here. The six macrolevels adopted by the focus group were

1. traditional criteria inspired by the iron triangle;
2. project participant– and stakeholder–related criteria;
3. project owner–related criteria;
4. health, safety, and security;
5. external environment–related criteria; and
6. project organization and management–related criteria.

It was suggested that health, safety and security should be a macrocategory by itself, because of the high importance of these criteria for water infrastructure projects. On the other hand, deliverables-oriented criteria were put under the stakeholder-related macrocategory, tied to user expectations and needs. The main reason for this is explained by the well-predefined user needs in these types of projects. That is, they are focused on fulfilling existential needs for clean water and access to sewage systems.

To determine which criteria were shown to be to most important theoretically, a further step was undertaken, as described in the next section.

Categorizing Project Success Criteria Using Relative Frequencies

After the project success criteria were categorized by the focus group, the relative frequencies of project success criteria and project success criteria categories were calculated, because these frequencies are a metric of their significance. Number of authors reffering to a certain criterion in both sets of relevant literature (recent and early), as well as the sum of reffeement in recent and early literature (Eq. 1), was joined to each criterion. The relative frequency of a criterion refers to the number of authors referencing it divided by the total number of references of all success criteria (Eq. 2). The relative frequency of criteria categories is expressed as the mean value of relevant frequencies of joined criteria (Eq. 3).

The number of authors referring to a success criteria Ki is

$$NA(Ki) = NAr(Ki) + NAe(Ki) \quad (1)$$

The relative frequency of success criteria Ki is

$$f(Ki) = NA(Ki)/N\text{total} \quad (2)$$

The relative frequency of success criteria category KKj is

$$f(KKj) = \Sigma fKi(j)/NKi(j) \quad (3)$$

The results of this analysis are given in Fig. 2. Criteria categories are named as in the adapted breakdown made by the focus group.

From Fig. 2, the following conclusions may be drawn:

- Within the macrocategory of the traditional success criteria, the most represented criteria are those of the well-known iron triangle: time, cost, and quality.
- In the macrocategory of project participant and stakeholder satisfaction, the most important criteria are related to contractor and user. Contractor satisfaction traditionally is related to the iron triangle and execution phase. On the other hand, user satisfaction is predominant for project success after handover.
- In the project owner macrocategory, the most important criteria are related to client and investor satisfaction. In addition to the general satisfaction of clients and investors regarding the project, the other most significant criteria are investment return, profit, and contribution to strategic goals in the context of future effectiveness and growth.
- In the context of the fourth macrocategory, the most important criteria are health, security, and safety, followed by project influence on the environment. This shows the extreme importance of the absence of accidents, injuries, and thefts, as well as ecological and other catastrophes related to the project in the context of its success, as well as improved health level of end users.
- In the macrocategory of external environment, the most important criteria are related to the contribution of the project to the profession, and then to social and political goals.
- In the macrocategory of project organization, the most significant criteria are those related to the development of the project management system, then communication criteria and criteria related to the satisfaction of team members with the project, as well as satisfaction of the project manager.

Project Success Criteria Categorization—Transport Engineering Focus Group Results

This first test confirmed that the proposed success criteria could be categorized and aligned with practice for water infrastructure

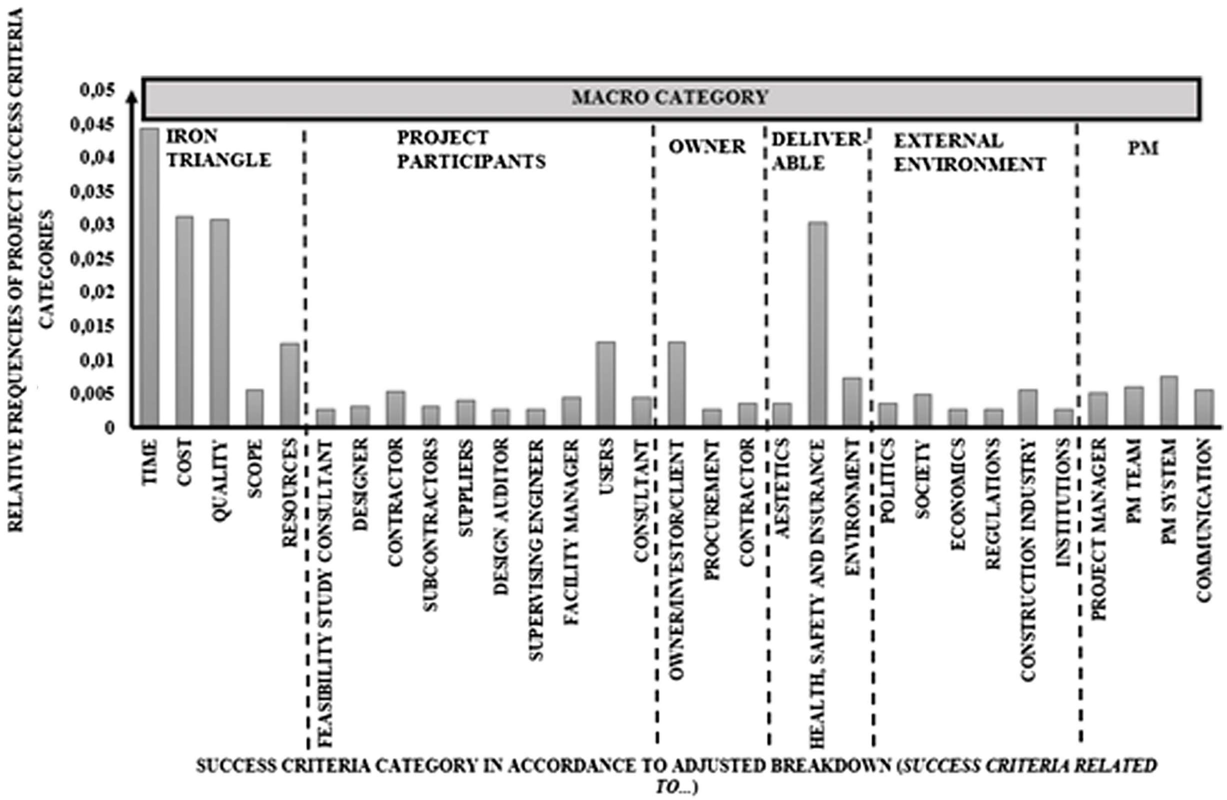

Fig. 2. Relative frequencies of project success criteria categories.

projects. For a second test, another focus group representing experts in transport engineering projects was formed using the same principles as described previously. The results confirmed similar key findings about categorization possibilities. The second focus group also selected six main macrolevels, and their selection was rather similar to that of the first test. They selected traditional criteria, project participants and stakeholders, client-related criteria, technical set of criteria, external environment related, and internal aspect related as organization and management. The focus group declared traditional criteria to be preeminent, which reflects the strong influence of the iron triangle in the engineering project managers' mindset, probably related to the pressure to which they are exposed in their daily work.

Both focus groups structured the 133 success criteria in similar formats. We found that differences between the expert groups were limited. Therefore, we continued to seek the baseline model which might represent an initial general breakdown of project success criteria, applicable in engineering projects. For practical use, it is expected that practitioners can tailor it to their experiences, the special features of groups of projects, and unique characteristics of project environments; therefore, versions and alternatives of the breakdown might be expected.

Project Success Criteria Categorization

Based on experiences from the two focus group tests as well as our own practice and records of the engineering projects, we proposed the final breakdown in which the identified criteria were sorted and grouped. It does not differ much from those suggested by the focus groups. We introduced project deliverable as an important macrocategory for engineering projects, in which several criteria can fit. We found that a graphical representation was mostly appropriate for easy communication and understanding within the profession. The breakdown structure was proposed because it supports hierarchical grouping and easily shows different levels of information. During this analysis we structured a breakdown, which, in our opinion, reflects the evolution of research ideas on the topic including all 133 different project success criteria. Because the final picture is quite large, due to size and format limitations we present only two master levels of breakdown; the first level shows 6 categories, which are subdivided into a further 29 categories at the second level (Fig. 3). This macrolevel of categories represents a general breakdown for engineering projects based on studies and researchers' point of view, as well as practice feedback. It could be tailored or modified for the observation of a special group of engineering projects or different regions or specific stakeholders' needs. The aim of this study was not to define the importance of each individual criterion; however, information about their relative frequencies from section "Categorizing Project Success Criteria Using Relative Frequencies" could provide a starting point for further analyses in this direction. It is clear that each stakeholder has their own perspective, and each project presents specific situation features, so adaptation and tailoring are an integral part of the approach suggested here.

The first level of the breakdown of project success criteria scheme consists of six macrolevel categories:

1. traditional criteria inspired by iron triangle;
2. project participant– and stakeholder–related criteria;
3. project owner and user success–related criteria;
4. project success criteria related to deliverables;
5. external environment–related criteria; and
6. project organization and management–related criteria.

The six criteria macrocategories at the first level of the breakdown demonstrate the genesis of the project success models up to this point. Within each macrocategory, a total of 29 categories of project success criteria are categorized at the second level, whereas

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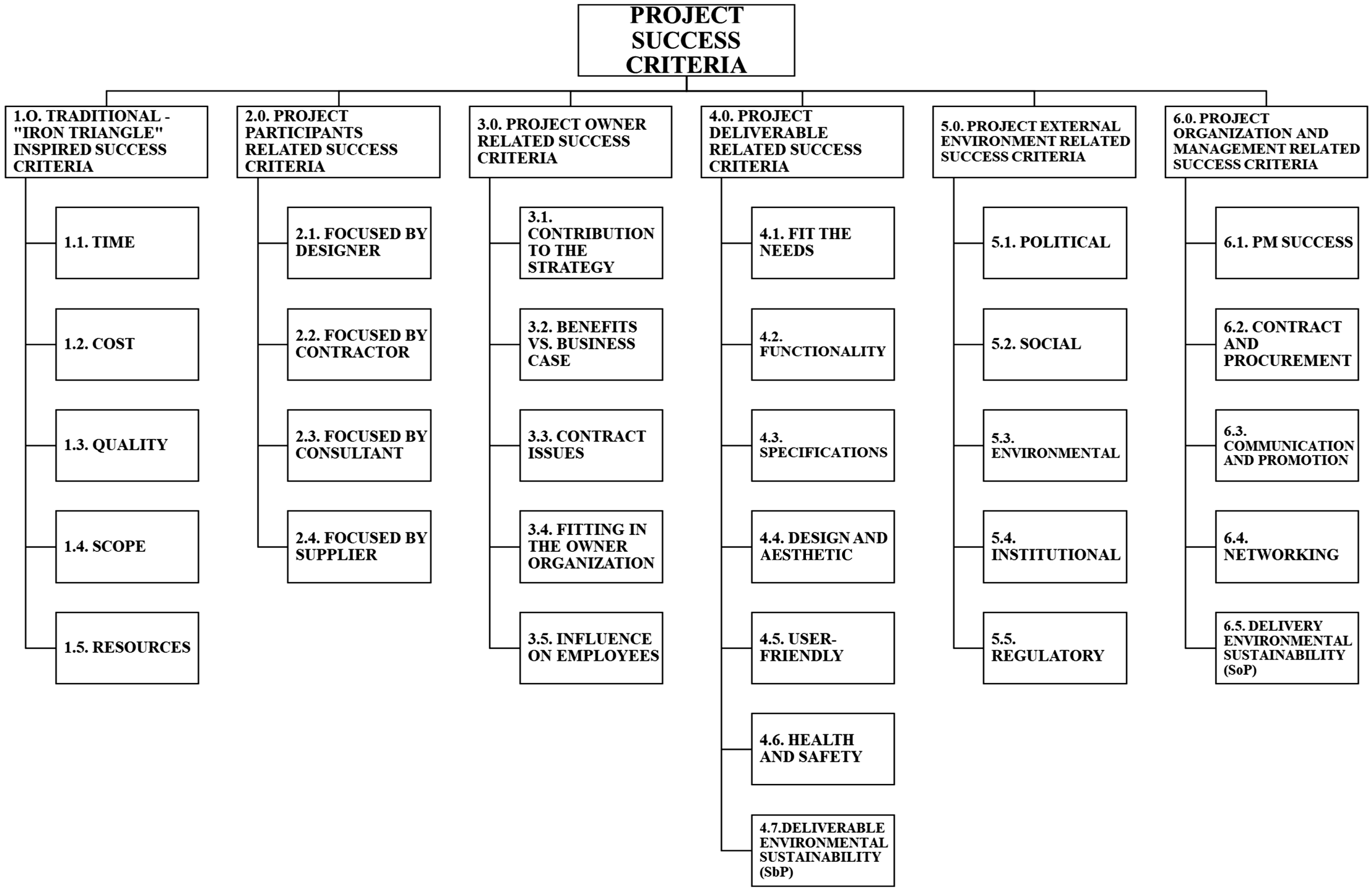

Fig. 3. Project success criteria breakdown structure based on the literature review and focus group results, adapted by the authors.

the third level includes all identified criteria in a structured way. The third level is the most operationalized level, and can be used for specific measuring of the performance for that particular criterion. The first macrocategory, Traditional project success criteria, consists of the classic criteria related to the iron triangle—time, cost, and quality—with two more, scope and resources. The criteria of scope and resources are linked to the iron triangle's structure to complete the success package, in which scope covers deliverables and resources covers processes, and they assure efficiency and effectiveness in delivery. The next macrocategory, Project participants' and stakeholders' expressed expectations, represents the goals of different interested internal groups. Usually, they are single-issue interest groups with a simple approach to benefit from the project, and if their needs are met, they judge the project to be a success. This criteria category is based on the principle of the multiple-win business standard, in which each party should achieve, at minimum, part of its own interests and objectives. In that way, the project creates value for a wider audience, which is positive for the economy in a long-term perspective. On the other hand, it brings subjectivity, short-term perspective, and challenges for project management to balance the package. While trying to find the balance between different stakeholders' expectations, which sometimes can be mutually exclusive, the project manager may define the balance as a multiobjective optimization problem in which a Pareto optimum is sought. Macrocategory 3.0 represents the project owner and user, who are excluded from the previous group due to their different roles and interests, which take both short-term and long-term perspectives. Usually, these go much further than the delivery phase, because a project's deliverables could influence many aspects of their position and organization. Consequently, more-complex numerous criteria subcategories are found on the next level of the cascade compared with the cases of other project participants. The fourth macrocategory is related to project deliverables and has a specific subcriterion that is important for different engineering projects. To some extent it represents the user(s) of the product or service which will be delivered by the project. Mostly, in engineering projects, it applies to a product, for which specific features are requested, because otherwise usage could suffer, directly influencing success. This macrocategory partly overlaps with Macrocategory 1. 0, in which quality and scope also are present, but which is firmly tied to the delivery and iron triangle. Macrocategory 5.0, Project External Environment, consists of all the criteria categories related to project goal fulfilment in its wider environment—in political, social, economic, environmental, regulatory, and other contexts. This macrogroup represents external criteria which come not from direct project participants, but rather from other stakeholders and wider audiences which are not bound by the project contracts. The last macrocategory, Project organization and management, is composed of all criteria related to the project manager, team, management system within the temporary organization, communication, and others; dealing with project participants, protocols, processes, standards and so on; and represents project management success, which is a contributor to the project success. Based on a cross-check with the most recent literature, we particularly emphasized the criterion of environmental sustainability or planet through two aspects aligned with the literature (Dubois and Silvius 2020): sustainability by project (SbP), which addresses the sustainability of the deliverable or project product (Fig. 3, deliverable environmental sustainability);

and sustainability of project (SoP), which addresses the sustainability of the delivery and management process of the project (Fig. 3, delivery environmental sustainability).

Evolution of Success Criteria and Discussion

Cross-Check with Most Recent Studies

Because the initial literature review on the topic of project success criteria was made for the period to 2017, recent literature (2017–2021) in the field was studied to check our findings in the context of the most recent trends. Scopus was added to the list of previously used search engines. Moreover, because the expert meetings were limited to two sectors, broader applicability of this study's results is discussed.

This additional desk research showed that many studies still remain on the solid ground of the schedule, cost, and quality (Razzaq et al. 2018), with endorsement of several others criteria such as health and safety, environmental performance, participants' satisfaction, user satisfaction, and commercial value (Luo et al. 2017). The iron triangle, or project performance triangle is still filled with the criteria of the expectations of the project owner and stakeholders, and company's mission, vision, and objectives (Phong and Quyen 2017). This is also the case when speaking of public–private partnership projects, for which critical criteria include effective risk management, meeting output specifications, reliable and quality service operations, adherence to time, satisfying the need for public facility and service, long-term relationship and partnership, and profitability (Osei-Kyei et al. 2017). Krajangsri and Pongpeng (2017) stated that construction project success can be described by six criteria—environment, quality, safety, time, cost, and client satisfaction. The client or organization perspective becomes very important, mostly through the impact on the clients, impact on the staff, direct business and success, environmental damage reduction, and preparation for the future (Carvalho and Rabechini 2017). Frefer et al. (2018) stated that the surest way to perceive project success is to examine its alignment with strategic organizational objectives. A significant novelty is the clearer and more significant positioning of environmental criteria (Sabini et. al 2019). The traditional criteria clearly emphasize economic aspects, and the social and environmental pillars receive less attention because companies' survival in the long-term depends on their ability to be profitable. This also was stressed by Viswanathan et al. (2020), who measured project success via three criteria: performance, schedule performance, and firm performance. Alignment with organizational strategic goals also has become one of the four criteria pillars not only of construction projects, but also of programs in China, along with construction program performance, social harmony, and project stakeholders' satisfaction (Yan et al. 2019). The cross-check in the Scopus database suggested two main streams of the current success studies, and both indicated focusing and narrowing. The first stream is related to the particular type of engineering project, such as highway construction (Alleman and Tran 2021; Choi et al. 2020), power sites (Abdel-Basset et al. 2021), petroleum and petrochemical industry (Faraji et al. 2021; Shariatfar et al. 2019), space industry (Decadi 2021), waste treatment (Uren et al. 2021), or IT (Hussain et al. 2021). Significant research was conducted of highway construction projects, in which a link between contracting methods and criteria such as schedule, cost, and change orders was investigated (Choi et al. 2020), as well as procurement method (Alleman and Tran 2021). The second stream leads to particular aspects of engineering project such as green building aspects and sustainability (Ahmad et al. 2021), contracting (Faraji et al. 2021), project team (Hussain et al. 2021), and posthandover stage (Fahri et al. 2020). No additional criteria were found in those studies which could not fit into those investigated previously in this study, and the findings mostly were coherent with the identified criteria in the breakdown suggested in this paper (Fig. 3).

Evolution of Engineering Project Success Criteria

The literature study and the tests performed resulted in several key findings about success criteria evolution over the last few decades

- Project success and success criteria have been popular research topics for decades, and this will continue. The comprehensive study of previous publications confirmed that numerous success criteria were suggested in the selected key research articles, many of which were repeated. Our study identified 133 different criteria suggested in papers published over decades related to engineering projects. Despite the progress of research thinking, the topic still is open to further research. Indeed, it is evergreen, but still the topic is moving forward, although it revolves around the foundations laid by early studies.
- Separation into the two periods of research studies—those before 2011, and those after 2011—proved that the research community had formed a consistent set of project success criteria by 2011 which has not changed much during the later period. The main new results come from the expansion and deepening of the topic, i.e., specific type of engineering project, specific issue, and conditions of application. A novelty also is the stronger positioning of environmental sustainability as a weighty criterion for success. Sustainability is probably the most complex element of success, because it reflects many aspects; it can be seen simultaneously as a factor and a criterion; it can be observed in different forms, i.e., of project (SoP) and by project (SbP) (Dubois and Silvius 2020); and it brings perception of adding more complexity and claiming more money. However, sustainability is just putting more light onto reality, which remains as it is, and Dubois and Silvius (2020) found "a strong positive correlation between sustainable project management and project success."
- There was no evidence of a unique definition of project success fitting all scenarios and time frames, but there has been a strong evolution of success measures over the last decades. By combining and merging developments and approaches to the topic, the authors suggested a project success definition that brings together the key research findings and recommendations over the last decades.
- The most prevalent criteria categories dealing with engineering projects in the literature are time, cost, quality and health, safety and security. Those were presented in the very first studies, but also are present in recent studies.
- Interestingly, the same so-called traditional criteria described by time, cost, quality, and safety were judged to be pre-eminent by practitioners in the focus groups, reflecting the strong influence of the iron triangle on the engineering project managers' mindset, due to the pressure to which they are exposed in their daily work. It is understandable, because their job finishes after delivery, at the end of the project execution phase, and they do not participate in the operational phase, in which project deliverables justify the whole project undertaking.
- No single criterion can measure project success. Rather, project success criteria come in a set of different criteria, and the set is tailored by factors such as sector, project type, and so forth, and consequently it is unique for each project. Consequently, the most dominant view of project success criteria aligns with the conclusions of Albert et al. (2017), who claimed that project managers should choose the "sound and well-rounded selection

of hard and soft criteria" for their projects individually on a project-by-project basis, due to the fact that there still is no consensus in the field.

- Criteria identified in our study were structured in a hierarchical view using the breakdown structure, in which upper levels aggregate key features of the related levels below. Different breakdowns could be created, but there will be components that fit in all variations (i.e., those inspired by the iron triangle).
- The study suggested that one initial breakdown could be used as a basic version for tailoring and adaptation based on different needs, characteristics, features, or interests within the specific project.
- The main considerations when dealing with project success criteria are related to the following: private–public–mixed, short term–long term, numerical–perception based, closed small group of beneficiaries–community and society, experts' view–politicians' view, project success criteria–project management success criteria, local–global perspective, and so on. It could be important to check each specific project against these categories prior to considering the breakdown structure.
- The check of the most recent literature published in the last three years, using also Scopus database, supported our findings but also confirmed that tailoring approach is a smart choice.

When observing the timeline and change of focus in project success criteria studies, we can see a strong tendency to move from a narrow scope and view to a much wider view, as well as from an exclusively numerical view to a combined numerical and perceptive view. Projects reflect the need for change over time, but also the position and predominance as well as the interests of particular groups. Although each phase focuses on a particular aspect, we are witnessing a cumulative approach in which recent developments are added to the previous ones, which makes the criterion theory increasingly demanding and complex. Fig. 4 shows the time sequence of the research focus of project success criteria, from early approaches on the left to the current approaches on the right. The figure shows the key groups of stakeholders and drivers in rectangles, and the associated resulting framework in circles, in which each earlier focus had an impact on all later foci, leading to integration of all criteria. The most important progress was made in the position of participant and stakeholder voices and sustainability (Silvius and Schipper 2016) when defining current criteria. In the 21st century, the voice of communities and even of society at large has become more and more important for declaring a project a success.

When going back to the roots of success criteria developments, we can examine the evolution of work and management within the human context. Long ago, management and organization studies focused primarily on work and finding ways to increase productivity (Fig. 5). This approach resulted from classical organizational theory, promoted by Taylor (1911) in the early twentieth century. The emergence of modern project management 50 years later focused project work on delivery and deliverables, and this approach and terms have been used widely (PMI 2017). Because delivery by itself is no guarantee of success, it is obvious that the real criteria should be based on the result of the project. Moreover, at the end, results should be transferred to benefits to be shared by project stakeholders and participants. The modern project management approach integrates different work stages ending with delivery, which can be justified by achieving the programmed result and measured by benefits created by such work and delivery.

One of the main conclusions from this study is that, over decades, project success criteria have shifted from focusing on simple work to focusing on complex benefits. This does not mean that previously selected criteria have been abandoned or rejected, but rather that they have been integrated into newer criteria (cumulative approach = previous + new), so overall project success criteria have become more complex following bigger-better-faster driving forces (Fig. 4). Secondly, benefits have stayed within the attributes that are important for different levels of human networking. This is logical, because ultimately each success is justified by benefit distribution among different human networks. However, recent trends show a dispersion in which more groups of stakeholders—such as communities, or even society—are taken into consideration at the top level of networking (Jensen et al. 2016). Societal representatives have become more visible and prominent within the list of stakeholders. Thirdly, as success has become considered to be a change for the better experienced and enjoyed by groups of people, there has been an important shift from money only or money primarily, to a more complex breakdown which expresses human needs and priorities in the 21st century, including sustainability considerations. Therefore, it is not unusual that for a particular project, one participant focuses on numerical success criteria and another selects criteria from qualitative benefits or a long-term perspective aligned with their own strategy. Such single-party tailoring seems to have

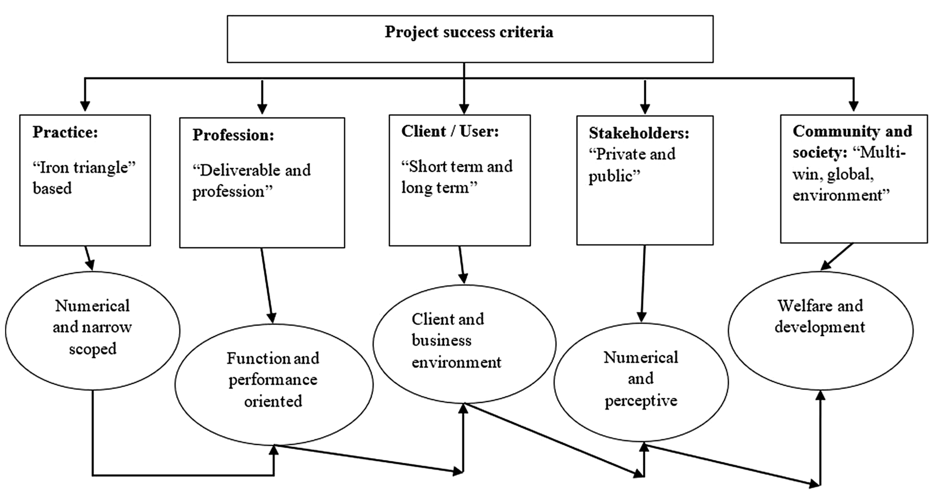

Fig. 4. Evolution of project success criteria development based on participants' and stakeholders' perspectives.

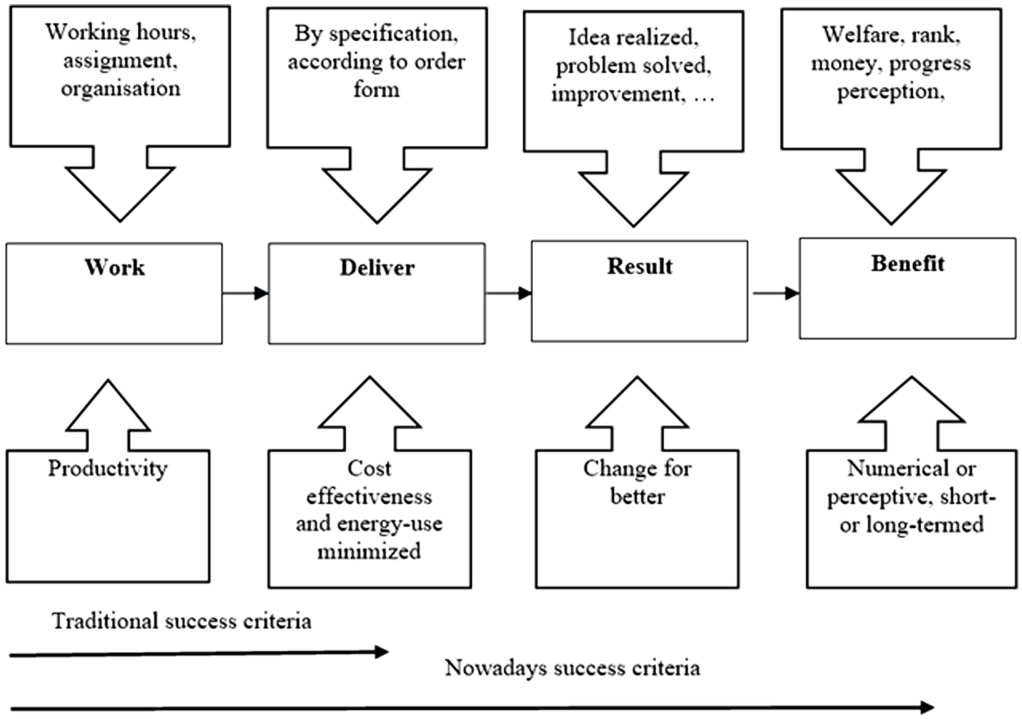

Fig. 5. Success criteria based on contribution and four-stage decomposition.

become a part of success practice, but it is acceptable only if it stays within the complex success definition, such as that described in the section "Project Success and Project Management." Obviously, it is important to share and exchange views on the importance of specific criteria among project parties (Koops et al. 2016). Overall, trends in project success criteria development follow the needs and development of the human community and will continue in this direction. The human future balances profit, people, and planet, and projects must comply as well (IPMA 2019).

The main findings of recent similar studies of project success show that many researchers deal in parallel with both project success criteria and success factors. Studies agree about the complexity of the theme, "while many still believe about no consensus among researchers of what constitutes projects success" (Frefer et al 2018). However, the main contributions to project management theory could be structured in two main streams. The first stream of research is focused on trends, guidelines, and general insights that apply to all types of projects or to specific sectors, such as engineering projects. The findings confirmed the iron-triangle (cost, time, and quality) to be an integral part of all approaches, as well as the relevance of criteria related to stakeholder groups and sustainability, but the authors found no indications that patterns for the selection of project success criteria have emerged, and still "project managers should choose the sound and well-rounded selection of hard and soft criteria for their projects individually on a project-by-project basis, due to the fact that no consensus on the field is still found" (Albert et al. 2017). The second stream of research has a narrower focus on a specific important factor or topic that is relevant to the project success criteria (Carvalho and Rabechini 2017; Luo et al. 2017; Meredith and Zwikael 2019; Müller 2019). Certainly, once selected and prioritized, a set of success criteria should be integrated with convenient metrics, so that project managers can track and evaluate performance against criteria. Because this question is beyond the scope of this research, we can state only that one convenient solution could lead to self-analysis of performance, an approach known from the Construction Industry Institute (CII 2020). Despite being a comprehensive program, the approach has the advantage that it "supports sector-specific metrics tailored to the unique needs of each sector" (CII 2020), which is an important feature for improving future project performance.

Comparing our results with the results of these other studies, we see alignment in terms of significance, complexity, the need for multiple criteria, the progress over time, and the lack of consensus about what exactly constitutes success. We also agree that the future might bring more-specialized and narrowly scoped studies of the topic of project success, including specific criteria. On the other hand, our study confirmed the lack of consensus about the approach to setting success criteria. The main contributions to the theory of project management of this study can be summarized in the list of success criteria for engineering projects from the literature and the proposal for a consolidated definition of project success. A detailed breakdown structure for success criteria hierarchical decomposition is proposed, and the third level of this detailed breakdown allows for detailed measurement of individual criteria. We also presented the evolution of the success criteria over the decades, and contributed to the discussion about the grounds for such developments. We expect that our study will provide inspiration for the future work, primarily due to its integrated approach to the selection of success criteria, taking findings over time and across the line of cognition, as well as providing guidelines and allowing tailoring for practice. Practitioners and project participants might find a basis for compromise during the process of setting a multiple-win scenario and balancing profit-, people-, and planet-related items.

Conclusion

Dynamic evolution of success criteria over decades is, in reality, tied to human development, and each project is under the constant pressure of bigger-better-faster compared with previous projects. In parallel, different groups of stakeholders and interested parties articulate their positions and expectations regarding project success. This study confirmed that project success, as well as project success criteria, have had continuous focus and evolution over the last decades. The analysis of selected key publications resulted in the proposal of a consolidated definition of project success, as well as an engineering project success criteria breakdown structure. The key findings from this study could provide directions for further research into the topic, in which each contribution over decades would be observed as the next step ahead. In parallel, practitioners could use the proposed breakdown as a starting point, while considering their own project and its specific features in its early stages. Overall, the study contributes to better understanding and definition of project success and engineering project success criteria. The main limitations come from the selection of the sample of publications, which focused primarily on engineering projects. However, it is our belief that the findings of this study could be relevant to a wider environment. In that sense, our main recommendations for future research are testing the given framework and proposed project success breakdown structure for different sectors or contexts (cross-sectoral or cross-cultural studies) and for different types of projects (infrastructure, IT, soft projects, governmental versus private, and so forth) to investigate the key success criteria per project participant. We believe that future research should focus on different specific aspects and contributions to the project success and their complex relations, rather than on the general scheme because reality is not captured simply.

Data Availability Statement

Some or all data, models or code that support the findings of this study are available from the corresponding author upon reasonable request with restriction referring to anonymized data (personal information of respondents, sensitive information on projects, etc.).

Notation

The following symbols are used in this paper:

$f(Ki)$ = relative frequency of success criteria Ki ($i = 1, 2, \ldots, 133$);

$f(KKj))$ = relative frequency of success criteria category KKj ($j = 1, 2, \ldots, 31$);

$NA(Ki)$ = number of authors referring to success criteria Ki ($i = 1, 2, \ldots, 133$);

$NAe(Ki)$ = number of authors referring to success criteria Ki in early literature;

$NAr(Ki)$ = number of authors referring to success criteria Ki in recent literature;

$NKi(j)$ = number of all success criteria Ki which are joined to success criteria category KKj;

N total = total number of referring of all success criteria; and

$\Sigma fKi(j)$ = sum of relevant success criteria frequencies Ki which are joined to success criteria category KKj.

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