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Applying system dynamics approach in software and information system projects: A mapping study

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ABSTRACT

Context: Software and information system are everywhere and the projects involving them are becoming more complex. However, these projects performance patterns are not showing improvement or convergence over time. Additionally, there is a growing interest in modeling the complexities involved in such projects for evaluating long-term impacts, especially the dynamic dimension.

Objective: This study aims to analyze how the system dynamics approach has been used in the scientific literature to model complexity in software and information system projects.

Method: The research approach used was a mapping study that combined bibliometrics and content analysis to draw the scenario of the research literature related to software and information system projects, identifying patterns, evolution trends, and research gaps.

Results: The results show the focus of the studies analyzed regarding the step of policy design and evaluation in the modeling process (46%), besides investigating software development projects (34%). This study also reveals that the most employed tools are simulations (78%) and the causal loop diagram (61%), but only 37% presented model equations. As for the software and information system projects success dimension, system quality has prevailed (73%).

Conclusion: The mapping showed that there is a gap of studies exploring the implementation and post implementation phases of software and information systems. Few studies explored the social components; the majority of the studies focused on technical aspects and did not report the complete steps of system dynamics modeling development process. This lack of information hinders the reproduction of past results for expanding and developing new studies.

1. Introduction

Even with the progress obtained in the project management area in recent decades, the improvement in the project success rate has not been significant [81]. Following this trend, software and information system projects have also shown no convergence of performance patterns over time [44,45,62].

There are challenges reported in software and information system projects in various contexts, covering complex information systems deployment such as Enterprise Resource Planning (ERP) [58], international software development [15], military IT projects [105], and the British government initiative to automate healthcare records that extended from 2000 to 2010 and was abandoned after costs reached the order of 5 to 10 billion dollars [116]. As a consequence, there is an increasing trend of research on complex projects [24,61] and the dynamic aspect stands out among the dimensions that characterize complexity [56].

Sterman [[120], p. 11] defines dynamic complexity as the “often counterintuitive behavior of complex systems that arises from the interaction of the agents over time.” Dynamic complexity arises because complex systems are constantly changing, tightly coupled, governed by feedback, nonlinear, self-organizing, adaptive, and policy resistant among other characteristics.

In project management literature, managing complexity is becoming an important issue because "complexity has become an inseparable aspect of systems" [19], and the complexity of projects appears to be increasing [78], which requires the application of critical thinking [91]. System dynamics is particularly suited for modeling and analyzing the complexity, because it is “a perspective and set of conceptual tools that enable us to understand the structure and dynamics of complex systems. System dynamics is also a rigorous modeling method that enables us to build formal

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computer simulations of complex systems and use them to design more effective policies and organizations" [119].

There is an understanding that software and information system projects are broader than just placing artifacts in operation. Their introduction alters the structure and culture of an organization; in addition, they change the way people think and work [85]. Defining success of those initiatives is also a non-trivial activity, and consequently, there is no consensus in the research community about how to define and measure it [31,111].

It is not surprising that currently the software inventory owned by a company usually represents a significant share of its assets [127]; thus they have a vital interest in preserving and maximizing the investments made to build their software libraries and to optimize future ones.

The demand for better results increased in the last years due to the growing pressure for faster deliveries, lower costs, scope flexibility, system interconnectivity and business dependence on information systems for operating daily activities. These demands require changes in software development processes and in the organizations adopting those systems, which require significant investment and are complex to evaluate. How is it possible to understand and to anticipate the impacts these changes present? "Software Process Simulation and Modeling" (SPSM) is one area of research that has sought to address this issue and has brought contributions to better evaluate scenarios and to predict potential impacts of proposed software process improvements [64,106].

Regarding the approaches applied in research related to modeling, simulating and conducting experimentation, system dynamics is the most commonly used simulation approach employed for better understanding problems and proposing new theories when compared to Discrete Event, Agent Based, Monte Carlo among others [17,130]. This approach was formulated in the 1950s [51] and has been gaining attention in several scientific areas since.

In spite of this prevalence, there are still few publications presenting the application of the system dynamics approach in the context of software and information system projects. In general, literature reviews of this area assess the use of simulation independently of the approach adopted [17,64,130]. On the other hand, literature reviews regarding the system dynamics approach are not specific to the software and information system projects context [72].

In this scenario, the present work aims at analyzing the publications exploring the use of the System Dynamic approach in software and information system projects, identifying the main authors, main studies, themes, patterns and evolution trends of the research field. This paper seeks to fill the identified gap by performing a mapping study for answering the following research questions: How did the literature on system dynamics applied to software and information system projects evolve over time? How has the system dynamics approach been used in research related to software and information system projects?

This work is organized in six sections. Section 2 presents the literature background on the core research constructs, particularly the use of the system dynamics approach to software and information system projects. Section 3 lists the research methods employed for collecting and processing the articles sample. Section 4 yields the results from bibliometrics and content analysis, followed by the discussions of the results in Section 5. Finally, Section 6 presents the conclusions, the limitations of the current work and suggestions for future research agenda.

2. Background

This section of the work offers an overview of the literature related to the evolution of the concept of project success and the application of system dynamics approach in software and information system projects.

2.1. Project success

The iron triangle composed of the dimensions of time, cost and quality [18], which was widely used as the evaluation criterion for project success (Berssaneti and Carvalho, 2015, Carvalho et al. 2016), has been discussed and expanded in recent years to incorporate reflections such as: success evaluation criteria may vary from project to project due to difference in size, complexity, and uniqueness [84]. The perception of success varies depending on the perspective of stakeholders and the moment of the project at which the evaluation was made [36]. It is necessary to distinguish success and failure of a project from the project management standpoint [109,129] in addition to considering the intangible aspects when evaluating success [26,76].

Other authors have analyzed the evolution of publications related to project success over the past decades and concluded that it consists of a multi-dimensional and inter-related construct [30,115]. Several authors suggest that it is a multidimensional construct that can includes project efficiency, impact on the team, impact on the customer, business and direct success, and preparation for the future [115] and, more recently, the environmental and social sustainability dimension [29,30,74]. In addition, the perception of success and the relative importance of the associated dimensions may vary according to the personality and to the nationality of the individuals involved, on top of the project and contract type [83]. Furthermore, there is a complex relationship between managerial, technical and behavioral aspects and their impact on success, which may be moderated by a set of variables such as industry, project type and country.

Due to the subject being multidisciplinary, several models have been proposed to assess and to measure project success. One of these studies is of particular interest, as it is focused on evaluating the success of initiatives involving information systems. It is also one of the most cited models in the area, having accumulated so far more than 2200 citations of its first version [39] and more than 1900 of its second revision [38], according to the *"Web of Science Core Collection"* database. This model offers a comprehensive user-centered approach to evaluate success consisting of six interdependent dimensions: information quality (desirable characteristics of the system outputs); system quality (desirable characteristics of an information system); service quality (quality of the service or support that system users receive); intention to use and use of the system (degree and manner in which staff and customers utilize the capabilities of an information system); user satisfaction (users' level of satisfaction with the information system); and benefits generated (extent to which the information system are contributing to the success of individuals, groups, or organizations).

Furthermore, we selected the DeLone and McLean [38], because their proposed success model represents a process and a causal representation of the six interrelated success dimensions. The focus on causal relationship is also one of the core elements of the system dynamics approach, which tries to explain complex behaviors from the interactions (feedbacks) among the components of the system [119]. A process model suggests that an information system is first created, containing a set of features and can be characterized as exhibiting various degrees of system and information quality. Next, users experience these features by using the system and are either satisfied or dissatisfied with it or its information output. Finally, the impact that each user experiences by interacting and working collectively results in organizational impacts. In contrast, a causal model evaluates the covariance of the success dimensions to determine the causal relationships among them. For example, a system with a higher quality evaluation