

What has the WASHES community discussed about Software Economics in the last years?

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Abstract. *Software Economics concentrates on enhancing the value derived from investments in software development and utilization, making it a critical aspect of decision-making in Software Engineering (SE). As such, this paper delves into the economic aspects of SE through a scope review on the Workshop on Social, Human, and Economic Aspects of Software (WASHES) proceedings. Following Boehm's seminal roadmap from 2000, we aim to portray advancements, identify emerging trends, and highlight challenges found in the WASHES research landscape over the past nine years. More specifically, this study contributes to academia by consolidating existing knowledge and suggesting future directions for software economics. Our findings offer industry stakeholders a forward-looking perspective on the current state, trends, and challenges in software development processes, enabling proactive strategies to enhance economic efficiency and strategic decisions.*

1. Introduction

The economic perspective within the Software Engineering (SE) community has been discussed since the 1980s, as exemplified by Barry Boehm's seminal work [Boehm 1984]. According to Boehm's, the major benefit of an economic perspective of SE lies in presenting a balanced view of potential SE solutions taking into account not only programming aspects but also the human challenges associated with delivering optimal information processing services within resource-limited environments [Boehm 1984]. Consequently, the overarching objective is to develop a more precise quantitative understanding of decision-making processes within the software development domain, particularly in resource-constrained scenarios [Boehm 2002].

In essence, Software Economics concentrates on enhancing the value derived from investments in software development and utilization [Boehm and Sullivan 1999]. In

other words, it is imperative to comprehend the interplay between economic factors, constraints, and conditions on one hand, and technical software considerations on the other [Boehm and Sullivan 2000]. Subsequently, this enhanced comprehension is leveraged to further increase software productivity [Foster and Foster 2014]. As discussed by Boehm and Sullivan (1999), establishing a link between technical software decisions and value creation becomes critical in the contemporary business landscape, where software investments are integral to all operational facets. Thus, this premise embraces that software development constitutes an ongoing investment activity, wherein stakeholders make decisions involving the allocation of valuable resources, such as time, human resources, and financial capital [Erdogmus et al. 2002].

In their contribution to the Future of Engineering at the 22nd International Conference on Software Engineering (ICSE 2000), Boehm and Sullivan outlined a roadmap for advancing software economics [Boehm and Sullivan 2000]. They advocated for developing tools and methods for managing software development as an investment, models for assessing benefits and risks, strategies for handling uncertainty and market forces, and resolving multi-attribute decision issues in design. Furthermore, they emphasized integrating economic and financial considerations into software development methods. Now, after more than 20 years, one can argue, in retrospect, the extent to which Brazilian SE researchers have responded to this call or maybe transcended its boundaries.

To partially address this issue, we may posit one of the current leading scientific venues in Brazil that also focus on software economics: the Workshop on Social, Human, and Economic Aspects of Software (WASHES). The first edition of WASHES was held in 2016, completing almost a decade by 2024 since its ideation in the Brazilian Symposium on Software Quality (SBQS 2015). This research landscape opens up the opportunity to gain insight into the WASHES community's discussions on the economic aspects of SE. Given this motivation, this paper has the aim of conducting a scope review covering all WASHES proceedings in order to 1) obtain a portrayal of the advances made in light of [Boehm and Sullivan 2000]'s roadmap and 2) identify emerging trends and challenges faced by the studies. While we acknowledge the existence of other reputable SE scientific avenues in Brazil, our focus on WASHES is particularly pertinent due to its explicit emphasis on the economic facets of software. Moreover, this focus aligns with the targeted objective of understanding the perspective of researchers within the WASHES community, although it may not necessarily represent the entire spectrum of Brazil's software economics research.

This paper makes contributions to both academia and industry. For academia, it enriches Brazilian research on software economics by systematically mapping studies published in the WASHES over the last nine years. This scholarly endeavor contributes to consolidating the knowledge base developed by the WASHES community and identifying emerging themes, thereby guiding future research directions on software economics. As a consequence, we have the opportunity to increase awareness of this relatively under-explored research avenue. On an industrial front, identifying the current state, emerging trends, and challenges may offer industry stakeholders a foresighted perspective, enabling them to proactively address issues and capitalize on opportunities to enhance the economic efficiency and strategic management of software development processes.

2. Research Design

To accomplish this scope review, we adapted the general guidelines suggested by Kitchenham and Brereton (2013) and Petersen *et al.*(2015). We were also inspired by other similar scope reviews [Pedro et al. 2023, Neves et al. 2023]. First of all, we defined two main **Research Questions (RQ)**:

- *RQ1: How WASHES's researchers have responded to the roadmap proposed by Boehm and Sullivan (2000) for software economics research?*

Rationale: This question seeks to gauge the specific responses made by researchers within the WASHES community to Boehm and Sullivan's seminal roadmap [Boehm and Sullivan 2000].

- *RQ2: What emerging trends and challenges on software economics have been discussed within the WASHES community?*

Rationale: This question aims to identify emerging trends and challenges discussed within the WASHES community about software economics.

In line with the previous RQ, we carried out the search and selection processes through the following phases: 1) **Initial Search**; 2) **Application of the Selection Criteria**; and 3) **Data Extraction**.

Firstly, we conducted the **Initial Search** by approaching all the proceedings published by WASHES, which are open and available¹ at SBC-OpenLib (SOL). We highlight that proceedings of the WASHES 2017 edition are only accessible on ACM and indexed on SOL. We performed the search in October 20, 2023, which returned 81 studies. We structured the acquired data within a Google Sheets file to facilitate efficient organization and analysis. The columns in this file included information such as Edition, Year, Title Study, Authors, Authors' Institutions, Author's state of Brazil, Abstract, Resumo, Keywords, Study' Category (full, short, or poster), and Download Link.

During the **Application of the Selection Criteria** phase, a set of inclusion and exclusion criteria were established to curate a selection of primary studies. The inclusion criterion was straightforward, necessitating that the study be published in WASHES, a requirement satisfactorily met by all studys considered, as they were sourced from the event's proceedings. As for exclusion criteria, a key determinant was the study's relation to software economics. To ensure rigor to this step, we followed the classical definition of Boehm and Sullivan (1999), where they conceptualize that: "Software economics is the field that seeks to enable significant improvements in software design and engineering through economic reasoning about product, process, program, and portfolio and policy issues". Moreover, to execute this exclusion criteria, a three-step protocol was devised and executed collaboratively by three co-authors. In the first step, the three co-authors independently analyzed only the studys' title, title, abstract, resumo, and keywords, consulting the entire text only when necessary to reach a confident judgment. Subsequently, each co-author independently compiled a list of selected studies and another list featuring ambiguous studies. The third step entailed a virtual meeting where the three co-authors deliberated on the studies (including the selected and ambiguous ones), resolving any doubt through consensus. Following this protocol, 14 Primary Studies (PS) were selected, as summarized in Table 1. This process ensured the precision and relevance of the selected primary studies for further analysis.

¹<https://sol.sbc.org.br/index.php/washes/issue/archive>

In the **Data Extraction**, our approach involved an in-depth analysis of the selected studies quantitative and qualitative facets, focusing on elucidating the landscape of software economics addressed by the WASHES community. We systematically gathered data about the studies publication details, authors, affiliations, and geographic distribution. Additionally, we quantitatively analyzed metrics such as publication years, proportion of full and short studies, distribution of studies by Brazilian state, and number of citations. Qualitatively, an inductive open-coding approach was applied to distill and categorize relevant data from the studies to answer our two RQ. To ensure the rigor of our qualitative analysis, one co-author independently conducted the initial coding process, and subsequently, two other co-authors performed the meta-analysis and validation. In turn, to enhance the reliability of the findings, four collaborative meetings were undertaken among these three authors to refine the codes and establish coherent categories iteratively. In average, these three co-authors account for 14 years of experience in SE research. In addition, all the data underpinning this work is openly available via our supporting repository [Araújo et al. 2024], ensuring transparency and accessibility.

Table 1. List of Primary Studies (PS).

ID	Edition	Reference	Author’s state	Category	Type
PS1	1	Monteiro <i>et al.</i> (2016)	PA	Short	Solution
PS2	3	Graciano Neto <i>et al.</i> (2018)	GO	Full	Evaluation
PS3	4	Nunes and Farias Jr. (2019)	PE	Full	Evaluation
PS4	4	Monteiro Neto and Furtado (2020)	AP	Short	Evaluation
PS5	5	Calado and Souza (2020)	PE	Full	Philosophical
PS6	5	Chueri <i>et al.</i> (2020)	RJ	Full	Validation
PS7	5	Coutinho <i>et al.</i> (2020)	CE	Short	Evaluation
PS8	5	Imamura <i>et al.</i> (2020)	RJ	Full	Evaluation
PS9	5	Silva <i>et al.</i> (2020)	PE	Short	Evaluation
PS10	6	Oliveira <i>et al.</i> (2021)	CE	Full	Solution
PS11	6	Lopes and Gadelha (2021)	AM	Short	Evaluation
PS12	7	Velasco and Carvalho (2022)	GO	Full	Philosophical
PS13	8	Valença <i>et al.</i> (2023)	PE	Full	Experience
PS14	8	Menolli <i>et al.</i> (2023)	PR	Full	Evaluation

3. Results and Analysis

3.1. Characterizing the Primary Studies

Figure 1 illustrates diverse publication years and types range. Publications span from 2016 to 2023 (excluding 2017), indicating a spread across multiple years. Consequently, editions range from 1 to 8 (excluding the 2nd WASHES), reflecting coverage of editions over time. Notably, 2020 had the highest number of primary studies (5). Regarding the study category, most (64%) are classified as full and 35% as short. Figure 1b shows the geographical diversity regarding institutions and states from the first author. Institutions vary from federal universities and science institutes to research centers in different states

of Brazil, including Pernambuco, Goiás, Rio de Janeiro, Ceará, Pará, Amapá, Paraná, and Amazonas. No research institution had more than one primary study, however Pernambuco was the Brazilian state with most studies (4). This result suggests a certain representation of different regions of Brazil. Such diversity can enrich the perspective of the studies by bringing different regional contexts to the addressed topics.

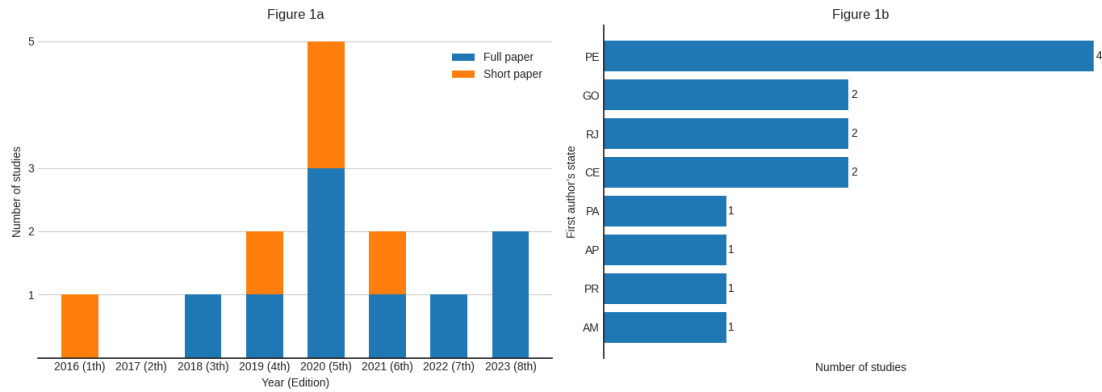


Figure 1. Primary studies characterization.

Table 1 also presented the research type (see the sixth column) of the PS following the research type classification provided by Wieringa *et al.* (2006): Evaluation Research, Opinion Paper, Personal Experience Paper, Philosophical Paper, Proposal of the Solution, and Validation Research. Most studies (57%) applied Evaluation Research. In addition, some studies developed Proposal of Solution (14%), Philosophical Paper (14%). Furthermore, the other research strategies comprised only one study each (7%), such as Validation and Personal Experience. Lastly, the study with the highest number of citations (six) according to the Google Scholar was PS8.

3.2. Advancements by WASHES in Light of Boehm and Sullivan's Roadmap

More than 20 years ago, Boehm and Sullivan outlined a seminal roadmap for advancing software economics [Boehm and Sullivan 2000]. This work was published at 22nd International Conference on Software Engineering (ICSE 2000) with the aim of discussing “how a sophisticated economic perspective on software design promises to significantly improve the productivity of investments in software-intensive systems”. In summary, the proposed roadmap emphasized the need for a strategic investment approach to software engineering covering the concerns depicted in Figure 2, which illustrates intermediate outcomes, dependence relationships among them, and important feedback paths by which models and analysis methods will be improved over time. For more details about the roadmap, we suggest to see the original work. Following these themes suggested on the roadmap, we investigated how the primary studies are related to them.

PS1 discussed organizations' challenges in developing quality software, highlighting strategies such as outsourcing and acquisition management. In particular, they noticed difficulties managing suppliers and the quality of acquired products. For this reason, they investigated agile approaches to managing supplier agreements, combining agile principles and practices with CMMI-DEV. This study aligns with the topic of “*Better tactical and strategic SW/IT product, process portfolio design decision-making*” (where SW/IT

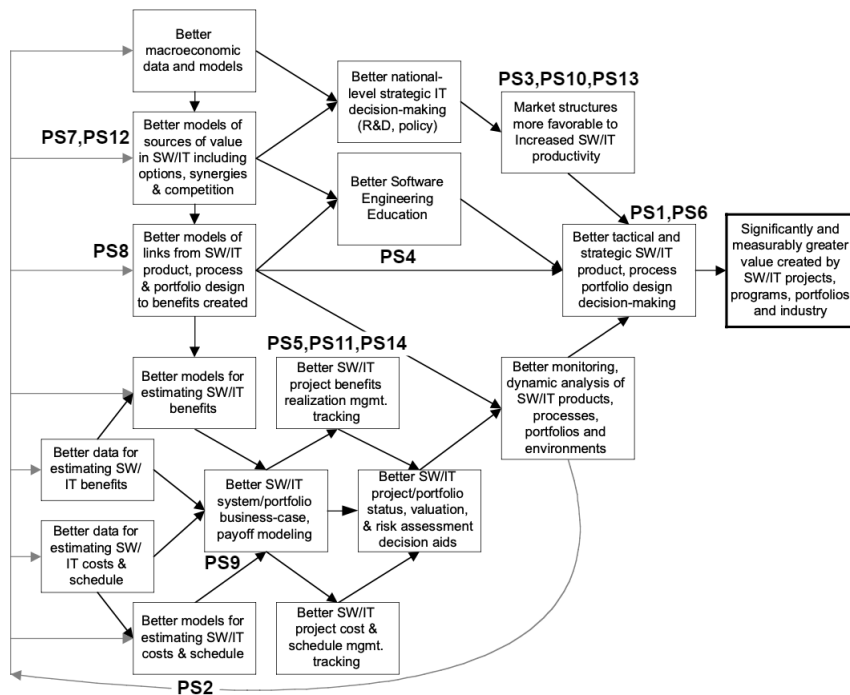


Figure 2. Roadmap for research on software economics [Boehm and Sullivan 2000] and the related Primary Studies (PS)

refers to software/information technology) by addressing the value of tactical and strategic sourcing decisions covering synergistic partnerships through the integration of agile principles and practices with CMMI-DEV methodologies.

PS2 proposed a simulation-based method for predicting acquisition costs in Systems-of-Systems (SoS) engineering, considering compatibility and functionality. The authors emphasized the need to analyze the minimum constituent set and compatibility for cost-effective SoS design, showing promising results in predicting costs and supporting architectural decisions. This study contributes to the topic of “*Better models for estimating SW/IT costs & schedule*” by offering a method that enhances cost estimation accuracy and supports architectural decisions through detailed analysis of constituent compatibility and functionality in SoS.

PS3 aimed to identify best practices to reduce turnover in IT organizations. The method included a literature review and qualitative research with managers from companies in Porto Digital, using an online semi-structured questionnaire. The results aimed to improve organizational people management by identifying best practices for addressing turnover. This study relates to “*Market structures more favorable to Increased SW/IT productivity*” by addressing the role of effective people management in fostering stable and productive workforce environments, thereby enhancing overall productivity within the software and IT market.

PS4 examined the key factors influencing the employability of software engineers. A survey was conducted with professionals to assess the relevance of identified challenges. Knowledge gaps were found in certain subjects concerning years of service and level of education, alongside optimism regarding the employability of highly quali-

fied professionals. This work contributes to “*Better Software Engineering Education*” by identifying knowledge gaps and informing strategies to tailor education programs towards addressing industry-relevant challenges and enhancing the employability of professionals in the software engineering field.

PS5 explored the digital maturity context, identifying organizational dimensions and critical indicators through a systematic literature review. They divided the dimensions into technical and human perspectives, emphasizing the importance of leadership, culture, and people. The authors pointed out the need for greater focus on the human perspective to achieve digital maturity, highlighting gaps in formulating and evaluating digital transformation strategies. This study aligns with “*Better SW/IT project benefits realization management tracking*” by clarifying the significance of considering leadership, culture, and people factors in effectively tracking and realizing benefits throughout projects.

PS6 presented an exploratory study on the perception of technical, human, and organizational factors in social innovation platforms, adapting software ecosystem factors to this context. The study discussed the technical situation of social innovation ecosystems in Brazil, which are still in an early stage compared to other more developed ecosystems. This study refers to “*Better tactical and strategic SW/IT product, process portfolio design decision-making*” by clarifying the need for comprehensive consideration of diverse factors in the design decision-making process, particularly in emerging ecosystems like social innovation platforms, to facilitate informed tactical and strategic choices.

PS7 explored the societal impacts of blockchain technology across various sectors, particularly in healthcare and finance, through a literature review, online surveys, and qualitative analysis, focusing on understanding its value and implications. This study related to “*Better models of sources of value in SW/IT, including options, synergies & competition*” by investigating the impact of blockchain on society and various sectors, shedding light on new sources of value creation and competition dynamics in software and IT ecosystems.

PS8 investigated the perception of IT professionals in a Brazilian public institution regarding governance mechanisms in SoS. Using a survey with managers and software developers, difficulties, benefits, and influences on technical, organizational, and behavioral governance factors were identified. The analysis revealed challenges related to these factors, highlighting the importance of governance in a complex context of information production for planning in a large public institution. This study aligns with “*Better models of links from SW/IT product, process & portfolio design to benefits created*” by examining the interplay between governance factors and information production complexities, elucidating the pathways through which effective governance contributes to realizing benefits in large-scale IT projects.

PS9 analyzed the importance of financial planning for IT startups in the Metropolitan Region of Recife (PE). The authors explored literature review and survey research to identify characteristics of entrepreneurs, financial planning, and challenges faced, resulting in effective practices for financial organizations. This study aligns with “*Better SW/IT system/portfolio business-case, payoff modeling*” by examining characteristics of the financial planning adopted by startups and the difficulties they encountered for the sustainability of the business.

PS10 introduced a platform and methodology for idea and startup registration and support aimed at economic recovery. The authors detailed software development, a seven-level methodology, and the platform's role in fostering innovation and socioeconomic improvement. This study contributed with "*Market structures more favorable to Increased SW/IT productivity*" by proposing a platform and methodology to support startups, contributing to a more conducive market structure for increased software and IT productivity through innovation and economic recovery initiatives.

PS11 investigated the impact of seasonal and elective management changes on software development teams in the public sector, analyzing their influence on service delivery and addressing relevant questions concerning the nature and process of these changes. This study is related to "*Better SW/IT project benefits realization mgmt. tracking*" due to examining how management changes affected software development teams and service delivery, contributing insights into tracking and managing project benefits realization among fluctuating management scenarios.

PS12 presented a systematic mapping study to identify research horizons and potential paths regarding blockchain and Non-Fungible Token (NFT) technologies, including domains, applications, challenges, and opportunities. The authors emphasized challenges in software development and legal aspects such as data ownership and intellectual property rights. Hence, this study aligned with "*Better models of sources of value in SW/IT, including options, synergies & competition*" by examining the challenges and opportunities associated with blockchain and NFT technologies, offering discussions into the software development lifecycle for tokens, and addressing legal considerations.

PS13 discussed interventions by Porto Digital to address skill gaps and align supply and demand for software developers in Recife's (PE) IT sector. The authors aimed to bridge the gap between academia and industry through increased enrollment in IT courses, contributing to skill gap literature and practically aiding industry-academia collaboration. This study is related with "*Market structures more favorable to Increased SW/IT productivity*" by proposing interventions to align supply and demand for software developers, fostering a more efficient market structure.

PS14 examined the impact of transitioning software development teams from in-person to remote work due to the COVID-19 pandemic, categorizing challenges and benefits observed through qualitative data analysis. The authors emphasized the importance of well-defined processes in facilitating adaptation to remote work for software companies. This study refers to "*Better SW/IT project benefits realization mgmt. tracking*" by exploring the effects of transitioning to remote work on software development teams, providing insights into tracking project benefits realization among changing work mechanisms.

According to the results, the diverse range of studies presented in this section reflect the multifaceted nature of software economics research and its implications across various domains. These studies provide practical solutions and theoretical frameworks to inform decision-making and drive positive outcomes in the software industry by addressing demands such as workforce turnover, acquisition cost prediction, and governance mechanisms. Furthermore, exploring market structures, benefits realization management, and strategic partnerships emphasized the importance of holistic approaches in maximizing value creation and realizing the full potential of software and IT investments.

3.3. Unveiling Trends and Challenges on Software Economics depicted by WASHES

After analyzing all the primary studies, we have identified three major trends and challenges associated with software economics. As such, the Figure 3 presents these **trends** (upper part) and **challenges** (lower part), including the respective related primary studies.

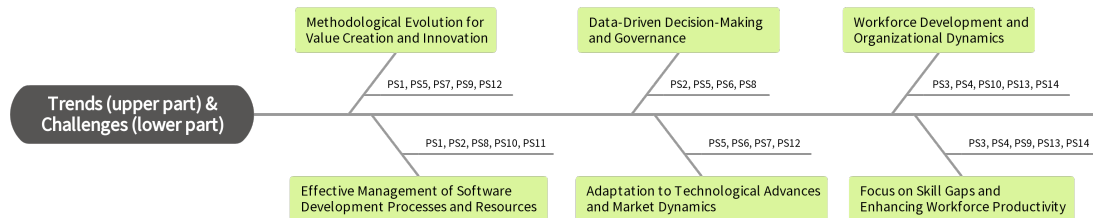


Figure 3. Categories of trends and challenges addressed by the primary studies.

Concerning the **trends**, we identified a focus on methodological evolution for value creation and innovation, as observed in studies such as PS1, PS5, PS7, PS9, and PS12, which propose new methodologies integrating agile principles, emphasizing the human perspective in digital transformation, and investigating the societal impacts of emerging technologies as blockchain. Secondly, there is a growing emphasis on data-driven decision-making and governance, which is evident in studies such as PS2, PS5, PS6, and PS8. These studies approach the importance of leveraging data-driven approaches and robust governance mechanisms to deal with complex software projects effectively. Lastly, there is a third trend toward addressing workforce development and organizational dynamics, exemplified by studies like PS3, PS4, PS10, PS13, and PS14. These studies delve into different aspects of workforce development and organizational dynamics to foster productivity and innovation within software organizations, offering contributions into reducing turnover, supporting startups, and managing changes. Collectively, these three trends emphasize the evolving landscape of software economics, shaping the efficiency and productivity of software development processes.

Regarding the **challenges**, there is the need of effectively managing software development processes and resources, as depicted in studies such as PS1, PS2, PS8, PS10, and PS11. These works highlight the complexities of managing suppliers, predicting acquisition costs, and navigating governance mechanisms in large-scale projects, emphasizing the importance of efficient resource allocation and process management. Secondly, adaptation to technological advances and market dynamics is challenging, as seen in PS5, PS6, PS7, and PS12. These studies discuss the need for organizations to continuously adapt to evolving technologies and market trends, emphasizing the importance of strategic planning and organizational agility in response to changing dynamics. Lastly, the challenge of focusing on skill gaps and enhancing workforce productivity is exemplified in PS3, PS4, PS9, PS13, and PS14. These works explore different aspects of workforce development, including reducing turnover, identifying employability factors, and supporting skill development initiatives, underscoring the importance of nurturing a skilled and productive workforce. Therefore, all these challenges serve as valuable research agenda in software economics, pinpointing demands where further research and innovation could be helpful for academia and industry.

4. Discussion and Final Remarks

Software Engineering Economics concentrates on enhancing the value derived from software development and utilization investments. As such, one of the leading venues in Brazil focused on software economics is the Workshop on Social, Human, and Economic Aspects of Software (WASHES). Given this context, we aimed to conduct a systematic mapping study covering all WASHES proceedings in order to 1) obtain a portrayal of the advances made in light of [Boehm and Sullivan 2000]’s seminal roadmap, and 2) identify emerging trends and challenges faced by the studies.

In terms of results, by examining each primary study and comparing them to the roadmap, we addressed our first research question (*RQ1*), evaluating how WASHES researchers responded to the roadmap’s directions. The studies covered, for example, better models for estimating SW/IT costs & schedule, market structures more favorable to increased SW/IT productivity, better SE Education, and others. In the light of our primary studies, we also categorized three significant trends and challenges to answer our last and second research question (*RQ2*). In summary, the trends involved methodological evolution for value creation and innovation, data-driven decision-making and governance, and workforce development and organizational dynamics. On the other hand, the challenges encompassed effectively managing software development processes and resources, adaptation to technological advances and market dynamics, focusing on skill gaps and enhancing workforce productivity.

Therefore, this paper contributes to academia by systematically mapping software economics studies in the WASHES community over nine years, consolidating existing knowledge and guiding future research directions. We also shed light on emerging trends and challenges, potentially increasing awareness of this research avenue. On an industrial level, we provide actionable insights into the current state, emerging trends, and challenges, facilitating proactive problem-solving and strategic management in software development processes to enhance economic efficiency. Overall, these findings indicate an integration of [Boehm and Sullivan 2000]’s roadmap into the research made by the WASHES community, showcasing a valuable endeavor to addressing the evolving nature of software economics. However, it is important to note the need for further research on other themes from the roadmap, particularly those relating to strategic concerns.

Recognizing the threats to the validity [Petersen et al. 2015], we implemented measures to mitigate them. Descriptive validity was ensured through meticulous data collection and rigorous coding, supported by openly available data via our supporting repository [Araújo et al. 2024], ensuring transparency and accessibility. While our focus is on the WASHES papers, potential limitations to generalizability are acknowledged through clear scope descriptions, with the study not aiming to represent the broader software economics research landscape fully. Interpretive validity was maintained by engaging three experienced researchers for independent analysis and a transparent analytical process.

Future work refers to expand the analysis to include publications from other Brazilian and international scientific SE avenues, providing a more comprehensive understanding of trends and challenges in software economics. Moreover, exploring additional dimensions that have possibly emerged since [Boehm and Sullivan 2000]’s seminal work presents an opportunity to enrich the discourse and capture the evolving landscape of software economics.

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