Investigating Professionals' Perceptions on the Software Supply Network Model in a Proprietary Educational Software Ecosystem

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*Abstract. **Research Context:** Modeling helps understand the structure, actors, and interactions in software ecosystems (SECO). The software supply network (SSN) is one of the best-known SECO modeling notations. In a previous study, we proposed an SSN model for a proprietary educational SECO, namely the SOLAR SECO, and identified the need to analyze this SSN model from the professionals' perceptions. **Scientific and/or Practical Problem:** The practical use of SSN models is still poorly explored, and little is known about how professionals perceive and apply them in real SECO. **Proposed Analysis:** This work analyzes this SSN model based on professionals' perceptions to identify issues and challenges. **Related IS Theory:** Socio-technical Theory, which explains the way the interaction between social and technical elements affects professionals' perceptions and use of artifacts, such as the SSN model. **Research Method:** We applied a questionnaire and conducted semi-structured interviews, analyzing the responses qualitatively. **Summary of Results:** Professionals perceived the model as useful for visualizing actors and supporting communication, but not for identifying new functionalities. **Contributions and Impact to IS area:** This study offers empirical evidence and a methodological procedure to support modeling and analysis of other SECO cases.*

1. Introduction

Software-intensive systems have become increasingly ubiquitous, large, and complex, being distributed, heterogeneous, and composed of interdependent components in several application domains [Nakagawa et al. 2023]. Such systems are usually centered

on a software platform and form a socio-technical network [Hanssen and Dybå 2012, Abreu and Coutinho 2020]. This perspective aligns with the Socio-technical Theory [Trist 1981], which emphasizes that the effectiveness of systems depends on the joint optimization of their social and technical elements. The software engineering and information systems communities have used the ecosystem metaphor to describe those systems usually centered in a software platform and named them software ecosystems (SECO) [Dhungana et al. 2010, Jansen 2020]. The SECO community has published several secondary studies in the last decades [Barbosa et al. 2013, Manikas and Hansen 2013, Manikas 2016, Malcher et al. 2023, Zacarias et al. 2025] that mentioned the modeling in this context.

[Barbosa et al. 2013] and [Manikas and Hansen 2013] considered modeling a strategic topic and an important field in the SECO domain. However, the lack of information, practices, and tool support for SECO modeling often leads organizations to reinvent solutions, limiting decision-making support [Pant and Eric 2017, Jansen et al. 2019, Malcher et al. 2023]. According to [Pant and Eric 2017], modeling can support decision-makers by enabling structured reasoning about coopetitive strategies through information visualization. Some studies highlight the need for further research on current modeling practices in SECO, grounded in real scenarios and practitioners' perspectives [Jansen et al. 2015, Sadi and Yu 2015, Pant and Eric 2017]. Building on this motivation, in a previous work [Coutinho et al. 2017], we modeled a proprietary educational SECO based on a virtual learning environment (VLE), called SOLAR. This modeling activity adopted the Software Supply Network (SSN) notation [Boucharas et al. 2009], complemented by specific recommendations from [Costa et al. 2013].

In the previous work [Coutinho et al. 2017], we highlighted the need to analyze the SSN model of SOLAR SECO from the professionals' perceptions involved in its development. According to [Sadi and Yu 2015], most modeling techniques applied in the SECO context have not received sufficient effort regarding experimentation and evaluation in real case studies and by practitioners. Hence, this work aims to analyze the SSN model of SOLAR SECO from the professionals' perceptions involved in its development to identify emergent issues and challenges. We applied a questionnaire and conducted semi-structured interviews with professionals to do so.

The main contributions of this work are: (i) the definition of a methodological procedure specifically tailored for analyzing an SSN model within a proprietary educational SECO, which emphasizes specific challenges and dynamics of a SECO; (ii) an analysis of the elements of such an SSN model according to the insights gathered from professionals in a real practical case of a proprietary educational SECO, addressing the limited access to data that typically characterizes this type of ecosystem; and (iii) the identification of findings about an SSN model that extend beyond traditional software or system models, indicating opportunities for further research in other ecosystems. These contributions advance the Information Systems field by providing empirical results on modeling practices and offering methodological guidance for analyzing real SECO cases. This work addresses the Grand Research Challenges in Information Systems in Brazil (I GranDSI-BR) by contributing to the modeling of complex socio-technical systems and digital ecosystems [Boscarioli et al. 2017].

The remainder of this paper is organized as follows: Section 2 presents the back-

ground and related work; Section 3 describes the research method; Section 4 presents the results; Section 5 discusses these results; Section 6 presents threats and limitations; and Section 7 concludes the work with final remarks and future work.

2. Background

This section presents the main definitions for understanding this work: SECO modeling and SOLAR SECO. It also discusses related work.

2.1. Software ecosystems modeling

Although there is no consensus regarding how to represent the elements that are part of a SECO, several modeling techniques have been used to describe them, such as Software Process Engineering Meta-model (SPEM) [Pettersson et al. 2010], Technical Ecosystem Modeling Notation (TECMO) [Seidl and Aßmann 2013], and Unified Modeling Language (UML) [Van Angeren et al. 2011]. However, these techniques mainly focus on modeling the software platform itself and do not address the involved actors and the relationships between them [Sadi and Yu 2015].

To overcome these limitations, other works have proposed modeling approaches that consider not only the software platform but also the actors and their relationships. For example, [Pant and Eric 2017] proposed a model-based approach for analyzing strategic moves in SECO using i* and game trees to represent dependencies and reciprocity between actors. Similarly, [Boucharas et al. 2009] proposed standardizing SECO modeling using the SSN strategy, a component of the Software Ecosystem Meta-model (SEM) designed to describe and analyze SECO. SEM provides a comprehensive view of the ecosystem, addressing not only the interactions between actors (as in the SSN) but also other important dimensions, such as 1) source: the origin of components and technologies within the ecosystem; 2) context: external and internal conditions that influence the behavior of actors in the ecosystem, such as regulations, market changes, or new technologies; 3) governance: mechanisms that regulate collaboration and competition between actors; and 4) evolution: how the ecosystem adapts and changes over time, including the entry and exit of actors and the introduction of new products or services [Boucharas et al. 2009].

SSN, in particular, is a series of linked software, hardware, and service organizations cooperating to attend to market demands and represents the structures of software supply chains in SECO [Costa et al. 2013]. Thus, its main focus lies in modeling the business relationships between the members of a SECO in terms of input and output flows between the actors [Handoyo et al. 2013]. [Costa et al. 2013] presented a summary of the SSN components that allow representing the main actors and their interaction in a SECO, as shown in Figure 1.

2.2. The SOLAR software ecosystem

The SOLAR SECO is based on a VLE designed to enable the creation of a virtual space to support face-to-face or online courses [Coutinho et al. 2017]. When the ecosystem is centered in a closed environment, where several platforms relate, the ecosystem is known as a proprietary SECO [Costa et al. 2022]. Proprietary SECO are typically protected by intellectual property (IP) management processes, and the value relates to monetary compensation [Manikas 2016]. Several secondary studies
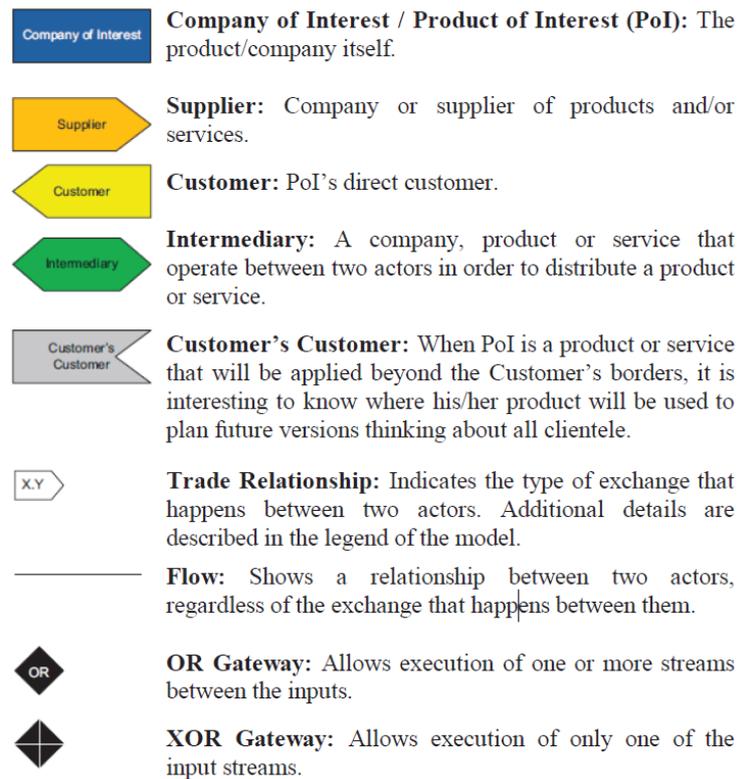
Company of Interest / Product of Interest (PoI): The product/company itself.

Supplier: Company or supplier of products and/or services.

Customer: PoI's direct customer.

Intermediary: A company, product or service that operate between two actors in order to distribute a product or service.

Customer's Customer: When PoI is a product or service that will be applied beyond the Customer's borders, it is interesting to know where his/her product will be used to plan future versions thinking about all clientele.

Trade Relationship: Indicates the type of exchange that happens between two actors. Additional details are described in the legend of the model.

Flow: Shows a relationship between two actors, regardless of the exchange that happens between them.

OR Gateway: Allows execution of one or more streams between the inputs.

XOR Gateway: Allows execution of only one of the input streams.

Figure 1. SSN elements representing the main actors and their interaction in an SECO. Source: [Costa et al. 2013].

[Manikas and Hansen 2013, Manikas 2016, Alves et al. 2018] mentioned that proprietary SECO are little explored in the SECO literature. [Manikas 2016] explained that proprietary SECO do not necessarily make ecosystem information publicly available.

The SOLAR SECO is based on free software with an architecture that can be integrated with other environments. It adopts a client-server architecture, and its main software platforms are Ruby on Rails (development technology), several auxiliary graphical environment managers (GEM components) to automate development, PostgreSQL (database), Nginx (web server), Unicorn (Rack web server), and Linux (operating system) [Coutinho et al. 2017]. The client side consists of a web browser, HTML, and JavaScript, while the server side comprises the web server, software components, and database [Coutinho and Bezerra 2020]. Figure 2 shows the architecture of the SOLAR SECO in its web version.

The SOLAR SECO consists of the following modules: (i) integration core; (ii) user management and control access; (iii) VLE integrator with the university academic management system; (iv) interactive personal space; (v) evaluation and monitoring; (vi) content authoring tool; (vii) communication tools; (viii) content tools; (ix) administrative tools; (x) course tools; and (xi) collaborative and cooperative tools. The SOLAR SECO VLE is mainly available in its web version[1], which is its most common use, currently used in training and classroom courses. There is also the mobile version of the SOLAR SECO for iOS and Android, which has reduced functionalities [Coutinho and Bezerra 2020].
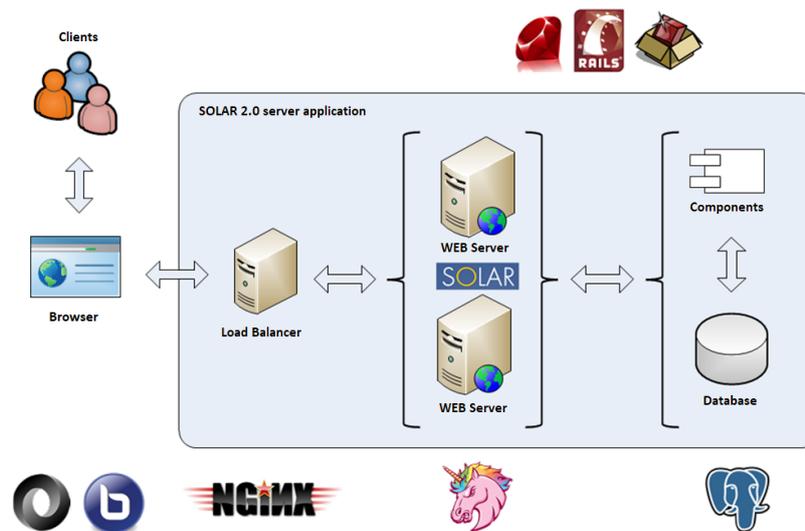
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[1] https://solar.virtual.ufc.br/

Figure 2. The SOLAR SECO architecture. Source [Coutinho and Bezerra 2020].

Surrounding the SOLAR SECO VLE platform, a set of relationships was formed: user relationships, technology supplier relationships, solutions developer relationships, and business relationships. Several systems have been developed over the common technological platform, and many versions and maintenance activities have also emerged. The provision of an application programming interface (API) for the construction of solutions for the platform also contributed to the integration and diffusion of the SECO. For example, the SOLAR SECO API enables the development of new applications/plugins, which external, internal, or independent customers can use in practice.

In a previous work [Coutinho et al. 2017], we created an SSN model of SOLAR SECO based on the mobile learning ecosystems (MLES) reference model. This model maps MLES elements to the SOLAR SECO to identify potential matches, supporting the identification of improvement points (such as better documentation of intermediate elements and deployment of new applications and services) and providing an initial overview of the ecosystem's structure and relationships. Figure 3 presents the SSN model of the SOLAR SECO, visualizing the main relationships between its elements.

2.3. Related work

[Sadi and Yu 2015] conducted a comprehensive study on how modeling techniques can support SECO design, defining descriptive and analytical requirements that modeling approaches should meet, such as: (i) representing collaborators; (ii) interactions and responsibilities; and (iii) analyzing incentives, risks, ownership, and sustainability. They examined five techniques (SSN, i*, business model canvas, value network modeling, and e³Value) and identified SSN as the only one specifically created for SECO. Complementing this perspective, [Schwichtenberg and Engels 2020] discussed the role and objectives of SECO modeling, emphasizing that models are essential to provide overviews of actors, relationships, and flows, as well as to support analysis and comparison of ecosystems. Together, these studies highlight both the requirements and the motivations for SECO modeling, while also stressing the need for methods and tools that support model maintenance and evolution.
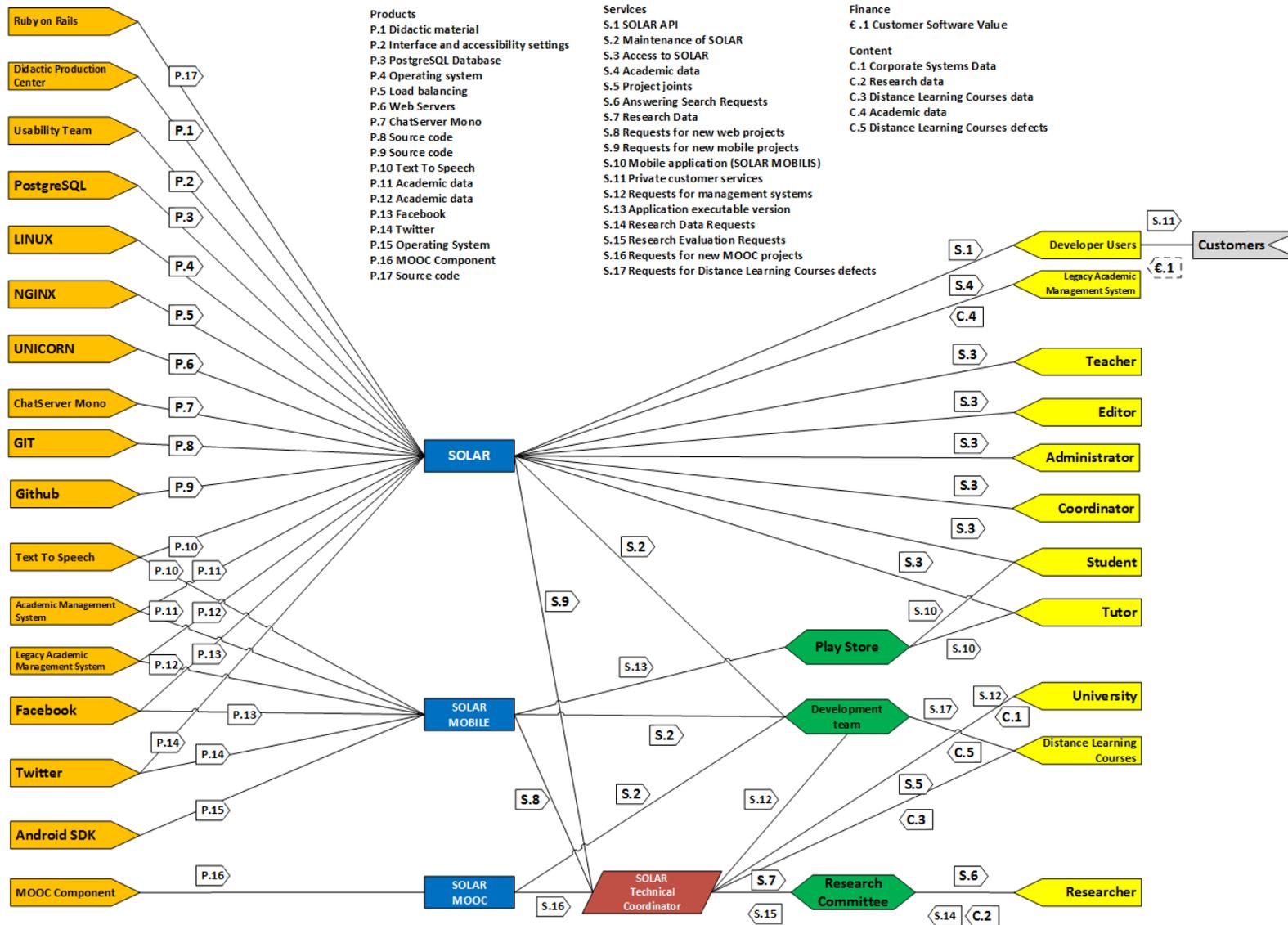
Products
P.1 Didactic material
P.2 Interface and accessibility settings
P.3 PostgreSQL Database
P.4 Operating system
P.5 Load balancing
P.6 Web Servers
P.7 ChatServer Mono
P.8 Source code
P.9 Source code
P.10 Text To Speech
P.11 Academic data
P.12 Academic data
P.13 Facebook
P.14 Twitter
P.15 Operating System
P.16 MOOC Component
P.17 Source code

Services
S.1 SOLAR API
S.2 Maintenance of SOLAR
S.3 Access to SOLAR
S.4 Academic data
S.5 Project joints
S.6 Answering Search Requests
S.7 Research Data
S.8 Requests for new web projects
S.9 Requests for new mobile projects
S.10 Mobile application (SOLAR MOBILIS)
S.11 Private customer services
S.12 Requests for management systems
S.13 Application executable version
S.14 Research Data Requests
S.15 Research Evaluation Requests
S.16 Requests for new MOOC projects
S.17 Requests for Distance Learning Courses defects

Finance
€ .1 Customer Software Value

Content
C.1 Corporate Systems Data
C.2 Research data
C.3 Distance Learning Courses data
C.4 Academic data
C.5 Distance Learning Courses defects

Figure 3. SSN model of the educational SECO. Source [Coutinho et al. 2017].

[Pant and Eric 2017] proposed a complementary approach to model strategic moves and reciprocity in coopetitive relationships within SECO by combining i* models and game trees. The authors used the i* modeling technique to represent the intentional structures of the actors and game trees to capture the sequence of strategic moves and their payoffs. This approach allows the analysis of decision-making dynamics among rival vendors who cooperate and compete simultaneously. They demonstrated the approach with the case of the Adobe Flash and Apple iOS ecosystems, showing how different strategic alternatives can lead to win-win, win-lose, or lose-lose outcomes. The study emphasized the importance of modeling strategic interactions and dependencies to understand how actors' decisions influence each other in SECO, especially in competitive environments.

[Kan et al. 2025] proposed an automated approach to visualize SECO with UML diagrams, focusing on tracking versions, dependencies, and security updates extracted from release notes. The approach provides mechanisms to represent the evolution of components and their interdependencies, highlighting how visualization can facilitate the understanding and maintenance of ecosystems. In addition, the study points out that automated visualization supports monitoring architectural changes and improves the capacity to analyze ecosystem dynamics over time. [Pinheiro et al. 2025] presented the *ECOS Modeling tool*, which supports SECO modeling using the SSN notation and provides a repository for models and evolution analysis. The tool enables collaborative model creation, versioning, and automated reports to analyze ecosystem evolution, and was evaluated with experts to assess its acceptance and perceived usefulness.

While [Sadi and Yu 2015] and [Schwichtenberg and Engels 2020] highlighted requirements, motivations, and objectives for SECO modeling, [Pant and Eric 2017] explored strategic reasoning about coopetition, and [Kan et al. 2025] focused on automated visualization of ecosystem evolution. In addition, [Pinheiro et al. 2025] advanced tool support for SSN-based modeling and reported expert-based acceptance results. However, these studies do not examine how practitioners perceive the usefulness and limitations of an SSN model when applying it in practice to understand and support activities in a specific SECO. Therefore, this work differs by investigating the perceptions of professionals involved in the development of a proprietary educational SECO (SOLAR SECO) regarding its SSN model.

3. Research method

Based on the results in previous work [Coutinho et al. 2017], in which we presented a preliminary study on the SSN model of the SOLAR SECO as seen in Section 2.2, we identified the need for further research about it. Thus, we aim to analyze the elements, relationships, and usefulness of the SSN model of the SOLAR SECO from the perception of professionals involved in the development of this ecosystem. To do so, we seek to answer the following research question (RQ): "*What are professionals' perceptions involved in the SOLAR SECO development about its SSN model?*"

We applied a mixed methods approach based on a questionnaire [Kitchenham and Pfleeger 2008] and semi-structured interviews [Hove and Anda 2005] for data collection. Therefore, this work was organized into three main steps: (i) presentation of the SSN model of the SOLAR SECO to the participants; (ii) application of a questionnaire and data analysis; and (iii) execution of semi-structured interviews and

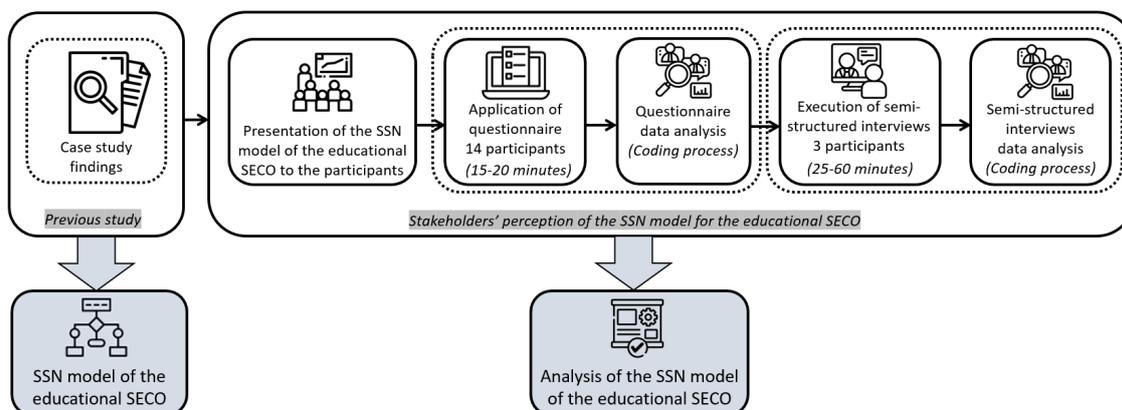data analysis. Figure 4 presents an overview of the research method.

Figure 4. Overview of the research method.

3.1. Presentation of the SSN model of the educational SECO

Initially, to obtain the perceptions of professionals (e.g., developers/ programmers, managers, consultants, and analysts) on the SSN model of the SOLAR SECO, we presented a definition of SECO and highlighted the importance of modeling for SECO. Next, we presented the SSN model of SOLAR SECO produced in a previous study (Figure 3), providing detailed descriptions of each model element. This face-to-face session lasted approximately 1 hour and 30 minutes. After the presentation of the model, together with detailed explanations of its elements, the participants had the opportunity to explore it during their activities in the development of the SOLAR SECO over a week. At the end of this period, we sent out a questionnaire containing questions related to the model, allowing them to answer individually and share their perceptions.

3.2. Application of a questionnaire and data analysis

We applied a questionnaire to verify whether professionals could understand the relationships between the elements of the SSN model of the SOLAR SECO and whether the model can support decision-making for the management and development of such ecosystem. We considered the guidelines suggested by [Pfleeger and Kitchenham 2001] for the construction and application of the questionnaire. Thus, we organized this process into three steps: (1) planning, (2) execution, and (3) data analysis.

In the *planning* (Step 1), we defined the target audience as professionals (e.g., developers/programmers, managers, consultants, analysts) working on the development of the SOLAR SECO. This ecosystem's platform had 14 professionals working on its development by the time the study was carried out. The questionnaire was available through Google Forms[2] and was divided into two blocks. In the first block, participants read and agreed/disagreed with the consent form before accessing the questions. In the second block, four questions on the characterization of the participants and three questions on the ecosystem aspects were presented to evaluate the SSN model of the SOLAR SECO. At the end of the questionnaire, we included an open field for comments to get further suggestions. Table 1 shows how we divided the questionnaire into closed (Q1, Q2, and Q3) and open (Q4, Q5, Q6, and Q7) questions on demographics and participants' perceptions.

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[2]https://forms.google.com

Table 1. Questionnaire items.

Characterization of participants		
ID	**Question**	
Q1	What is your academic degree? ***Closed question:*** Bachelor's, MBA (Specialization course), Master's, PhD	
Q2	What is your professional profile? ***Closed question:*** Teacher/Researcher, Practitioner (developer, systems analyst, others)	
Q3	What kind of software development projects have you participated in? ***Closed question:*** The SOLAR SECO, Other(s)	
Q4	What role(s) do you play (or played) in the SOLAR SECO? ***Open question***	
Questions on SECO aspects		
ID	**Question**	
Q5	Based on the presented concepts and the SSN model of the SOLAR SECO provided, in your opinion, what technical, business, and social elements do you think were missing? ***Open question***	
Q6	Do you think that there is a relationship or element from the SSN model of the SOLAR SECO that is confusing or unclear? If so, which and why? ***Open question***	
Q7	How could the SSN model of the SOLAR SECO support the decision-making process of the management and development of this platform? ***Open question***	

In the *execution* (Step 2), we sent out the questionnaire via email to 14 possible participants. We also sent out reminders over time. After the deadline set for data collection, we obtained 14 responses (reaching 100% of the possible participants). Participants were selected from the list of professionals who are internal to the SOLAR SECO and work on the platform development and evolution. This group corresponds to the entire internal team of this proprietary SECO at the time of the study and have roles related to software development.

Regarding the academic degree of the 14 respondents, four hold a Bachelor's degree, three have an MBA (specialization course), three have a Master's degree, and four have a PhD. In terms of professional profile, five are teachers/researchers, seven are practitioners (developers, systems analysts, or other roles), and two are both teachers/researchers and practitioners. Most participants work as developers, while others are involved in specific activities such as management, systems analysis, and accessibility evaluation. A summary of this characterization is presented in Table 2.

Table 2. Characterization of participants.

Question	Answers	Amount
Academic Degree	Bachelor's	4
	MBA (Specialization Course in Information Technology)	3
	Master's	3
	PhD	4
Profile	Teacher/researcher	5
	Practitioner	7
	Both	2
Role in the SOLAR SECO	Developer	5
	Systems analyst	1
	Developer and manager	1
	Systems analyst, developer and manager	1
	Interface/Graphic designer	2
	Accessibility Specialist	1
	Teacher/Researcher	1
	Not answered	2

In the *data analysis* (Step 3), we adopted an open coding approach to analyze the questionnaire responses [Charmaz 2006]. The data were organized in an electronic spreadsheet, enabling two authors (third and fourth) to code the responses, while the remaining authors reviewed the results. The team has solid experience in Software Engineering and Information Systems, with the first three authors having more than four years of experience and the others more than fifteen years.

During the open coding process, we divided the responses into coherent units (sentences or paragraphs) and added **preliminary codes** representing the key aspects mentioned by each participant. Subsequently, we agreed on a set of **focused codes** that captured the most frequent and relevant findings in the participants' perceptions. After performing the open coding, axial coding was used to group the focused codes into broader **categories**, as described by [Charmaz 2006]. To do so, the excerpts and codes were organized into a document, enabling the researchers to review and refine the main findings based on discussions in several iterative cycles. We considered 14 valid responses for analysis, and this step allowed us to discuss the results. Applying this questionnaire to SOLAR SECO professionals was also important for selecting interviewees for the following data collection phase.

Table 3 illustrates the coding process, showing one representative example of each of the four focused codes defined from the questionnaire responses: *missing social elements*, *missing technical elements*, *confusing or unclear elements*, and *helping decision-making*. The focused codes were grouped into categories based on semantic similarity and thematic relevance. Each category was supported by multiple responses from different participants that conveyed similar ideas, which allowed us to consolidate recurring perceptions rather than isolated comments. The complete set of questionnaire responses with their respective codifications is available as supplementary material [Malcher et al. 2025].

Table 3. Illustration of the questionnaire response coding process.

Transcript unit	Preliminary code	Focused code	Category
"Other important roles also operate in [omitted], such as academic secretaries and content developers. I think there should be some connection between the researchers and the development team." (Participant 12)	Mention of missing social roles and need for connection	Missing social elements	Social
"Since 'Text to speech' (which does not exist in [omitted]) was mentioned, it could be integrated and presented in the model." (Participant 1)	Suggestion to integrate text-to-speech feature	Missing technical elements	Technical
"I did not understand exactly what 'Content Editor' means." (Participant 8)	Confusion about meaning of a specific element	Confusing or unclear elements	Clarity
"[Omitted] SECO helps to understand all the interactions performed in the system." (Participant 2)	Helps understand interactions	Helps decision-making	Usefulness

3.3. Conducting semi-structured interviews and data analysis

Based on the analysis of the results obtained from the questionnaire application, we identified an opportunity for a further investigation of whether the SSN model of the SOLAR SECO added value to the development and evolution of the ecosystem, which brought new questions about the model. We considered the guidelines adopted in [Hove and Anda 2005] to develop the guide for the semi-structured interviews, which were organized into three steps: (1) planning, (2) execution, and (3) data analysis.

In the *planning* (Step 1), we defined the target audience as professionals involved in the development of the SOLAR SECO. The previously applied questionnaire allowed us to contact these professionals. We then invited the 14 participants, of whom three, with different roles, agreed to participate, enabling the scheduling of three semi-structured interviews. The interviews followed a semi-structured guide with open-ended questions, whose design was carefully considered to support participants' understanding. A consent form was sent before conducting the interviews. Table 4 presents the interview questions.

Table 4. Semi-structured interview questions.

ID	Question
QInter1	Do you believe the SSN model of the SOLAR SECO presented can add value to the development team? In what way? Could you give more details?
QInter2	Do you believe that the SSN model of the SOLAR SECO presented can help the development team in making management decisions?
QInter3	In your opinion, in which of the SOLAR SECO development activities could the SSN model of the SOLAR SECO be used?
QInter4	In your opinion, can the SSN model of the SOLAR SECO help in the identification of new functionalities for the SOLAR SECO?

In the *execution* (Step 2), we conducted the online interviews via Google Meet[3]. Two researchers (third and fourth author) conducted the interviews, and the other researchers reviewed the transcriptions. We requested recording all the content to allow its subsequent complete transcription. However, only one participant authorized the recording of the interview. We obtained the data from the other two participants through manual records (notes) made by the researchers, which were later reviewed by two researchers to reduce the risk of misinterpretation. No maximum time was defined, so the duration of the interviews varied according to the interviewee's availability and exhaustion of possible answers. All the information provided by the participants was kept confidential based on the consent form. We also characterized the participants to contextualize their perceptions. Interviewee 1 has 8 years of experience in educational management in the SOLAR SECO and has experience in software and hardware infrastructure. Interviewee 2 has 7 years of experience in the SOLAR SECO development. Finally, Interviewee 3 has 3 years of experience in the SOLAR SECO development.

In the *data analysis* (Step 3), we focused on examining the data collected in the interviews. We applied the same open and axial coding procedure described in Section 3.2 to analyze the answers to questions QInter1–QInter4 [Charmaz 2006]. This approach allowed us to identify preliminary codes, group them into focused codes, and then organize them into broader categories based on semantic similarity and thematic relevance. The analysis resulted in two focused codes: (i) perceived contributions of the model; and (ii) perceived limitations of the model. The interview excerpts and their codes were organized in a shared document to support discussions and reviews by all authors in iterative cycles. Table 5 illustrates the coding process, showing one representative excerpt of each focused code identified from the interview responses. The complete set of coded excerpts is available as supplementary material [Malcher et al. 2025].

Table 5. Illustration of the semi-structured interview response coding process.

Transcript unit	Preliminary code	Focused code	Category
"Looking at the SSN model of [omitted] SECO, I can identify who provides what and how they connect. It helps me see dependencies and how one change might affect others." (Interviewee 1)	Mentions that the model helps identify functionalities	Perceived contributions of the model	Positive
"The lines in the figure are confusing and it was hard to understand what was linked to what." (Interviewee 1)	Mentions difficulties with model readability	Perceived limitations of the model	Negative

4. Results

This work comprised the application of a questionnaire and semi-structured interviews with professionals involved in the development of the SOLAR SECO. The following sub-

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sections present the results obtained from these two instruments that provided an overview of how professionals perceived the SSN model of the SOLAR SECO, revealing both positive aspects and challenges.

4.1. Questionnaire

We considered the responses to the open questions Q5 to Q7 to analyze the completeness of the SSN model of the SOLAR SECO from the perceptions of professionals directly involved in its maintenance and evolution. Table 6 summarizes how many questionnaire respondents provided statements supporting each category.

Table 6. Questionnaire respondents supporting each category (Q5–Q7).

Question	Category	Participants
Q5	Technical (missing technical elements)	P1, P10, P11, P12
Q5	Social (missing social elements)	P12, P13
Q6	Clarity (confusing or unclear elements)	P1, P6, P8, P9, P10, P11, P12, P14
Q7	Usefulness (helps decision-making)	P2, P3, P5, P6, P7, P11, P12, P14

Q5 assessed whether any technical, business, or social elements were missing in the provided SSN model of the SOLAR SECO. No participants explicitly reported missing elements related to the business dimension. Instead, the reported gaps were restricted to technical and social aspects. Regarding technical aspects, two participants pointed out missing elements related to platform functionalities and integrations, suggesting that some elements currently used or required in the ecosystem are not represented in the model.

"Since 'Text to speech' (which does not exist in [omitted]) was cited, it could be integrated and presented in the model." [Participant 1]

"The representation of other integrations with other systems (virtual slate, virtual reality, and others) is missing." [Participant 11]

Two participants also mentioned missing social elements. One pointed out the lack of representation of some actors in the model, and another highlighted the need to improve the accessibility of the ecosystem platform so that this aspect can later be reflected in the model. These were isolated comments but indicate social elements currently not represented.

"Other important roles also operate in [omitted], such as academic secretaries and content developers. I think there should be some connection between the researchers and the development team." [Participant 12]

"The very issue about accessibility is a point that needs to be improved in [omitted] (focus on profiled users), to later be represented in the model." [Participant 13]

Q6 was related to the clarity of the relationships in the SSN model of the SOLAR SECO. Eight participants mentioned confusing or unclear elements or relationships in the model. One participant cited that some relationships represented in the model, such as the supplier element for Facebook and Twitter/X, no longer exist or never existed. Moreover, another participant suggested simplifying the nomenclature of one of the elements of the model to improve its understanding.

"There is no longer integration of the [omitted] SECO with Facebook, there has never been an integration with Twitter, and I don't know what 'Text to Speech' is. I don't understand what a legacy academic management system would be." [Participant 1]

"Shouldn't 'ChatServer Mono' be renamed to just 'Chat server'? I think that would be a better name for this element." [Participant 6]

Q7 was related to how the SSN model could support the understanding of the management and development processes of the SOLAR SECO. Eight participants said the model helps reflect on these processes. Four of them also mentioned aspects related to improvement and evolution. One highlighted the usefulness of visualizing actors and their relationships to better understand the platform's management and evolution. Another emphasized that understanding the whole scenario helps identify limitations and possibilities for new solutions.

"The fact of being able to visualize the various services used and system actors and their relationships can help manage and evolve the platform more effectively." [Participant 6]

"Understanding the whole scenario through the model makes us think about the limitations and solution possibilities for new features in the system. I was positively surprised by the model." [Participant 12]

4.2. Semi-structured interview

Based on the analysis of the questionnaire responses, mainly related to Q7, we identified the need to conduct interviews with some ecosystem professionals to obtain more detailed insights into whether the SSN model of the SOLAR SECO adds value to the development and evolution of this ecosystem. These interviews were designed to complement the questionnaire findings and clarify points that remained unclear in the initial analysis. We analyzed the interviewees' answers to the open questions QInter1 to QInter4 (Table 4) to understand these aspects.

We sought to obtain the perceptions of professionals involved in the development of the SOLAR SECO about its SSN model. Thus, QInter1 assessed whether this model can add value to the development team. The interviewees mentioned that the model could be helpful for understanding the ecosystem as a whole, its actors, and their roles. Interviewee 1 pointed out that it allows identifying the main actors involved in the ecosystem, while Interviewee 3 highlighted its usefulness for onboarding new team members.

"Yes. Looking at the SSN model of [omitted] SECO, I can visualize what functionalities [omitted] needs and who the actors need. In addition, I can understand who is in charge of the administrative side of [omitted] and who is responsible for identifying requirements directly with customers, such as [omitted] coordinators and administrators." [Interviewee 1]

"This model helps me explain [omitted] to new team members. They can get a general view and see how things are connected." [Interviewee 3]

QInter2 aimed to identify whether the SSN model of the SOLAR SECO could support the development team in analyzing the ecosystem. The participants indicated that the model helps analyze the impact of changes that can occur in the ecosystem. Interviewee 1 highlighted this benefit, while Interviewee 3 described how their perception changed after the discussion.

"Yes. It allows me to view the impact between the parties, which is very important for a management view." [Interviewee 1]

"Reading the article alone was not enough. After your explanation, it became clearer. Now I see value and plan to use it." [Interviewee 3]

In QInter3, most responses were positive regarding the SSN model of the SOLAR SECO as support for impact analysis in platform development. Participants noted that the model can be used together with requirements documentation to assess the impact of changes, although Interviewee 3 highlighted that the lack of updated documentation currently hinders its adoption and maintenance. Interviewee 1 emphasized its usefulness for analyzing impacts on architecture and components, while Interviewee 3 suggested including information on the ecosystem's historical evolution to support the analysis of architectural and technological changes over time.

"Maintenance and requirements: the impacts of changes can be verified through the requirements along with the model. Architecture: with requirements, you evaluate the impacts of changes, which can be visually verified on the infrastructure and components represented in the model." [Interviewee 1]

"The model could show historical evolution. It would allow us to discuss changes, like removed mobile features and stopped Facebook integration." [Interviewee 3]

In QInter4, we investigated whether the model could help identify new features (functionalities) of the SOLAR SECO. According to Interviewees 2 and 3, the model is unsuitable for identifying new features or startup projects because the visualizations show the current structure of the system but do not support the exploration of new opportunities. They also mentioned that the lack of updated documentation makes it difficult to incorporate new features and keep the model aligned with ongoing changes, which hinders its continuous update as the ecosystem evolves.

"It would not serve to identify functionalities but to use it as a query and evaluate the possible impacts of the changes added to [omitted]." [Interviewee 2]

"I don't think the model is good for new projects, starting from scratch. It would be better to use another way to identify new features and represent them in the model." [Interviewee 3]

5. Discussion

The main goal of this work was to analyze the SSN model of the SOLAR SECO to identify issues and challenges based on professionals' perceptions. Data were collected through a questionnaire and semi-structured interviews with professionals involved in the ecosystem's development. The combined analysis of these sources enabled result triangulation and a clearer understanding of how the SSN model is perceived in practice.

The analysis of the questionnaire (Section 4.1) and the interviews (Section 4.2) provided evidence to answer our RQ: *"What are professionals' perceptions involved in the SOLAR SECO development about its SSN model?"*. These results are in line with previous studies that highlight the role of SECO modeling in supporting shared understanding, communication, and ecosystem visualization [Sadi and Yu 2015,

Schwichtenberg and Engels 2020]. The results indicate that professionals perceived the SSN model as a useful artifact, providing a clear overview of the ecosystem, helping them visualize actors, roles, and relationships, and fostering communication and collaboration. They also reported that it helps onboard new developers, explain the ecosystem's structure, and analyze the impacts of changes, especially in maintenance and evolution activities. At the same time, they identified opportunities for improvement, emphasizing that the model does not support the identification of new functionalities or the planning of new projects, mainly because it represents only the current structure and depends on updated documentation to remain aligned with ongoing changes.

Some professionals mentioned possible improvements, such as including technical elements (e.g., integrations with external systems and accessibility features) and social elements (e.g., actors who play relevant roles but are not represented). They also suggested that integrating the model with complementary artifacts, such as requirements specifications and architectural documentation, could increase its effectiveness. Overall, professionals recognize the SSN model as useful mainly for visualization, communication, and impact analysis in maintenance and evolution contexts, while pointing out the need for additional elements and regular updates.

The findings of this study converge on three points: (i) the SSN model is useful for visualizing actors and relationships; (ii) it supports communication and onboarding; and (iii) it helps conduct impact analysis in maintenance and evolution activities. A minor divergence appeared regarding perceived usefulness before and after explanation of the model (e.g., Q7 versus QInter2), indicating that familiarity with the SSN notation directly influences perceived utility. The interviews also showed that the usefulness of the model depends on the availability of updated supporting documentation, as outdated information limits its adoption beyond visualization and impact analysis. The interviews helped explain the questionnaire trends by showing how visualization and shared vocabulary enable impact analysis, while the lack of updated documentation constrains broader uses of the model.

Professionals mentioned that the model helps clarify responsibilities (e.g., requirements gathering, infrastructure management, and coordination tasks) and supports onboarding by explaining the ecosystem's structure. This finding is consistent with [Sadi and Yu 2015], who argue that ecosystem modeling fosters a shared vocabulary and common understanding among professionals. In the same direction, [Schwichtenberg and Engels 2020] emphasized that SECO modeling serves objectives such as providing overviews of actors and relationships and supporting comparative analysis of ecosystems. Furthermore, [Kan et al. 2025] showed how automated UML visualizations can help track dependencies, updates, and architectural evolution, reinforcing the role of visualization in ecosystem understanding and maintenance. Our results reinforce these perspectives by showing that the SSN model has already been used informally as a communication and onboarding tool.

The professionals' perceptions can be interpreted through the lens of the Sociotechnical Theory [Trist 1981], which states that system effectiveness depends on balancing social and technical elements. The SSN model contributes mainly to the social dimension by promoting shared understanding and collaboration, while professionals perceived gaps in its technical dimension. This imbalance helps explain why the model has

been more useful for communication and onboarding than for tasks that require technical accuracy or frequent updates. According to [Knauss et al. 2012], incorporating new contributions requires alignment with existing elements and stakeholders' interests. This alignment becomes harder when relevant elements are missing or outdated, which is precisely the situation reported by the professionals.

The professionals also clarified that the model represents the current structure but does not support identifying new functionalities or opportunities (QInter4). This contrasts with expectations in the literature that SECO modeling can support strategic planning and innovation [Pant and Eric 2017]. In practice, they reported using the model mainly for communication, onboarding, and impact analysis related to maintenance and evolution. A few professionals also mentioned confusing elements, such as relationships that never existed (e.g., with Facebook or Twitter/X), which reinforces the importance of regularly reviewing and updating the model to keep it reliable.

In summary, professionals value the SSN model as a tool for visualization, communication, and impact analysis in maintenance and evolution contexts. They also recognize opportunities to strengthen its technical dimension through continuous updates and the inclusion of relevant elements to complement its strong social dimension.

6. Threats and limitations

We recognize that questionnaires and semi-structured interviews can introduce biases and contain ambiguous or incomplete questions, even with the precautions adopted by the researchers. Such limitations are typical of qualitative studies [Kitchenham et al. 2015], especially regarding the generalization of results. This study involved 14 participants in the questionnaire and 3 in the interviews, all of whom were professionals involved in the development of the SOLAR SECO platform at the time of the study. Although this number is small and no formal saturation procedures were applied, these participants are experienced experts and provided valuable insights. The triangulation of data sources, including questionnaire responses, interviews, notes, and qualitative coding, mitigated this limitation by supporting a consistent interpretation of professionals' perceptions. We also identified the following threats to validity:

External validity concerns the generalization of findings. This study analyzed a single real SECO case, and the results are not intended to be generalizable but to provide indications for future studies. The analysis focused on internal professionals of the SOLAR SECO, excluding external actors, which represents a limitation. To address this threat, we provide a detailed characterization of the SECO, its participants, and its processes, allowing readers to assess the applicability of the findings. Moreover, this scope is consistent with socio-technical evaluations of proprietary SECO. The qualitative approach was chosen to understand aspects difficult to investigate through quantitative methods. We do not claim that the perceptions reported here are representative of all SOLAR SECO professionals, but they can inform investigations in similar ecosystems.

Internal validity concerns uncontrolled factors that may have influenced the results, such as the subjectivity of self-reported data and the absence of a pilot study. These factors may have affected how participants interpreted and answered the questions. To mitigate this threat, the questionnaire and interview questions were carefully reviewed to reduce ambiguity and improve clarity.

Construct validity refers to the degree to which the study instruments adequately capture the intended theoretical concepts. A potential threat is that the structure and wording of the questions may not fully reflect the constructs under investigation. To mitigate this risk, the questionnaire and interview questions were reviewed by two independent researchers to assess their alignment with the underlying concepts. During the interviews, questions were clarified when necessary to avoid misunderstandings. Another potential threat is the absence of formal inter-rater reliability metrics in the qualitative coding process. To mitigate this threat, the coding was conducted by two researchers through iterative review cycles, with disagreements resolved by consensus.

Conclusion validity refers to drawing correct conclusions from the collected data. The interviews were recorded (when authorized), fully transcribed, and analyzed using a method already applied in similar studies. More than one researcher participated in the interviews and analysis to ensure reliability and to clarify doubts when recordings were not available.

7. Final remarks

This work analyzed the SSN model of a proprietary SOLAR SECO based on the perceptions of professionals involved in its development. The results addressed our RQ by showing that these professionals perceive the model as useful mainly for visualizing the ecosystem, supporting communication, facilitating onboarding, and assisting decision-making related to maintenance activities and analysis of the impacts of changes. They also pointed out aspects to improve, such as adding missing technical and social elements, ensuring updated documentation, and aligning the model with ongoing changes in the platform. These suggestions indicate opportunities to strengthen the model and better align it with development practices and stakeholder needs.

The findings are consistent with the Socio-technical Theory [Trist 1981], which states that system effectiveness depends on balancing social and technical elements. While the SSN model contributes to the social dimension by fostering shared understanding and collaboration, its contribution to the technical dimension is still limited due to the lack of updated information and missing elements. Strengthening this technical side could improve its usefulness for guiding development and supporting innovation.

This work contributes to the Information Systems field by providing empirical evidence on the practical use of SSN modeling in a real SECO. It highlights how professionals perceive its value and limitations, offering insights to guide future modeling efforts. For researchers, it reinforces the importance of considering technical, social, and business relationships in SECO modeling. For practitioners, it shows that the SSN model can support decision-making about maintenance activities, communication, and impact analysis when complemented by updated documentation and other artifacts (e.g., requirements and architectural specifications).

Although focused on a specific SOLAR SECO, the methodological procedure, the perception-based categories, and the lessons learned can support investigations of SSN models in other contexts, enabling comparisons across ecosystems and advancing the understanding of SECO modeling in practice. Future work includes: (i) investigating the needs and barriers for SECO modeling in different contexts and types (e.g., proprietary, open-source, or hybrid); (ii) integrating SSN models with complementary software engi-

neering artifacts to strengthen their role in ecosystem management; (iii) developing tool support to automate the updating and visualization of SSN models, reducing the risk of obsolescence and increasing their adoption in practice; and (iv) exploring the use of artificial intelligence techniques to support the construction, interpretation, and maintenance of SSN models in data-intensive ecosystem contexts.

Artifact availability

The raw data and all the steps necessary to reproduce the study are detailed in the supplementary material located at https://doi.org/10.5281/zenodo.18473097.

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