Digital Platform Business Model within the Model of SGE - System Generation Engineering: Definition and Classification in Cyber-Physical Systems

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Abstract

Adding internet technologies to mechatronic system solutions is the next step for Industry 4.0 and has a high potential for digital platform business models linked with cyber-physical system (CPS). The model of SGE – System Generation Engineering describes the development of systems on subsystem level. So far, no known research investigated a coherent definition explaining a digital platform business model in the model of SGE according to CPS. Within a four-phase methodology, a systematic literature analysis identifies and processes 55 relevant definitions and extracts a data set of 32 definitions after eliminating 23 duplicates. In a semantic analysis, crucial primary and externally linking terms, combined with five case study findings, reveal the artefact, an economic platform with five characteristics. After initially validating the artefact, a workshop and academic discussion result in an intermediate artefact, further validated in a subsequent expert workshop. Findings suggest the terms value added, infrastructure, exchange, interaction, and openness describe digital platform business models. Essential defining aspects must entail facilitating value added through a multisided market by integrating specific entities, providing an open and/or closed infrastructure for flexible and compatible networking components, integrating data between the CPS and the platform, creating trustworthy and economic value added through entities, and scaling by network effects. This paper shows how to extract a precise, coherent, valuable, and iteratively validated definition to create a common understanding within a research field. Practitioners can learn about the digital platform business model concept within the model of SGE, supporting knowledge creation, research, and product development of CPS in generations. The originality of this work lies in extracting a validated definition by applying sophisticated tools and methods to guarantee its robustness.

Keywords
Definition, SGE - System Generation Engineering, Cyber-Physical Systems, Digital Platform Business Model.

1. Introduction

In the business-to-consumer (B2C) market, the iPhone is a well-known example of product development in generations (Pfaff et al. 2023). Apple Inc. is a prime showcase of how strategic product development across multiple generations promotes new connection points for digital platform business models, most recently in augmented reality (AR) (Apple Inc. 2023). Introducing the Apple Vision Pro, an AR headset, represents a consolidation of different software and hardware elements from previous product generations on one new product. With its own operating system and applications, it mirrors a new digital platform business model interacting with physical products (Apple Inc. 2023). Pfaff et. al (2023) show that the model of SGE – System Generation Engineering provides a basis for describing the development of systems like the Apple iPhone in product generations, where the development of systems occurs on a subsystem level. The new development of subsystems occurs through attribute variation (AV) and principle variation (PV), whereas the adaptation takes place through carryover variation (CV) (Albers and Rapp 2022; Albers et al. 2022). Albers et al. (2020) highlight that business models can be seen as part of the product in product development. Hence, digital platform business models do not only occur in B2C markets. The high potential for digital business-to-business (B2B) platforms is shown in the fact that about 30% of industrial companies already use a digital platform (Lerch and Jäger 2020). As a result, it is becoming increasingly common to implement digital platforms in the B2B market (Shree et al. 2021). Mehami et al. (2018) claimed that adding internet technologies to mechatronic system solutions is the next step for Industry 4.0. Thus, the model of SGE can be used to describe the future development of mechatronic systems (Albers and Rapp 2022). These types of mechatronic systems are known as cyber-physical systems (CPS). CPS is a complex system connecting the physical and digital world based on integrating embedded computers, sensors, actors, communication networks, and software-based intelligence. They enable close collaboration between the physical environment and digital control, resulting in enhanced performance, efficiency, and flexibility (Trevino 2019). While CPS, like automated guided vehicles (AGVs), foster the digital transformation of products, product development has initiated a profound shift, reshaping the traditional boundaries of the IT solution landscape (Eigner 2021). Based on scientific databases, the underlying problem in the current state of research is the inhomogeneity of digital platform business model definitions (Wortmann et al. 2019), which is due to different focuses and perspectives. For instance, the Association of German Mechanical and Plant Engineering e.V. defined digital platforms in its white paper "Platform Economy in Mechanical Engineering" from April 2018 as "intermediaries who use digital technology to connect two or more market participants via platform and simplify or even enable their interaction" (Rauen et al. 2018). The fourth and latest edition used the term "platform based value creation networks in digital ecosystems" (Ditterich et al. 2022). The Federation of German Industries divided its guide into two categories German B2B platforms: data centric and transaction platforms (Ditterich et al. 2022). Brecht et al. (2023) suggest improving the role of digital platform business models in product development. It is essential to ensure a uniform understanding of CPS and digital platform business models within the model of SGE. According to Blumer (2013), terms provide comprehensibility and order. Thus, experience becomes clearer through abstracting and describing terms. It provides a scientific basis for further productive discussions in the topic area on the same perceptual level, so that knowledge and information can be formulated and communicated on a common basis (Blumer 2013). Combining CPS with digital platform business models within the model of SGE is a new research field requiring precisely defining concepts and terms. Thus, this paper aims to address the need for a distinguished definition by investigating the following research question: *How should a digital platform business model be defined in the model of SGE and classified in cyber-physical systems?* A four-phase research methodology was applied to answer the research question. Initially, a systematic literature review revealed 55 digital platform business model definitions; only considering the unique answers resulted in a final data set of 32 definitions. This data set was used to run the IBM SPSS Modeler Text Analytics software. The analysis revealed the concept of *digital platform business model* is closely connected to several elements, namely, *value creation*, *infrastructure, exchange, interaction,* and *openness*. This information, combined with findings from analyzing established companies with digital platform business models (five case studies), led to creating a first intermediate definition artefact describing several characteristics. This artefact was introduced and further developed in two consecutive expert workshops. These workshops led to the primary definition of a digital platform business model in the model of SGE. This paper is structured as follows. The next section explains relevant theoretical concepts to provide an understanding of the research context. The third section outlines the methodology. Section four represents the results of the semantic analysis as well as the expert workshops and provides the definition of a digital platform business model in the model of SGE. The final section includes a general discussion and concludes with final remarks.

2. Literature Review

2.1 Cyber-Physical System

Products and production systems face rapidly changing requirements. Fostering digital transformation of products and product development has initiated a profound shift, which reshapes traditional boundaries of the IT solutions landscape and expands the understanding of mechatronic systems (Eigner 2021). The goal is to integrate data and processes by enabling systems to interconnect and communicate (Putnik et al. 2019). When a system communicates via the Internet, it is termed Cyber-Physical System (CPS). Expanding mechatronic systems in the context of CPS focus on intelligence and communication capabilities (Eigner 2021). Demonstrated by the Google Lens example, CPS establishes a more intimate linkage between the physical and digital realms compared to mechatronic systems (Eigner 2021). CPS integrates embedded computer systems, communication networks, and software-based intelligence with the physical system components, enabling comprehensive real-time control, monitoring, and potentially optimizing physical processes (Eigner et al. 2012). The physical components continuously capture data from their environment using sensors. This information is transmitted to the cyber component, which analyzes and processes it in real time. Subsequently, control commands are sent to the actuators to execute corresponding actions. Through this bidirectional communication and real-time control, CPS facilitates adaptive and responsive controlling of physical processes (Pivoto et al. 2021). Consequently, efficiency and collaboration can be enhanced across the entire product lifecycle. It enables companies to operate with greater flexibility, innovation, and competitiveness, meeting the demands of an increasingly interconnected and digitized world (Trevino 2019).

2.2 SGE – System Generation Engineering

In modern-day-engineering, the actual percentage of “new developments” is below 10% (Albers et al. 2015; Kirchner 2020). This is why the classic subdivision into "new design, adaptive design, and variant design" lacks practicability, as stated by Pahl and Beitz (Pahl et al. 2007). The aim of product development is to achieve an innovative system generation with enough differentiating elements to distinguish it from previous generations and competing products (Marthaler et al. 2019). Innovation success with advanced, complex technical systems can only be achieved economically and with manageable risk by using existing solutions as references. With the model of SGE - System Generation Engineering according to Albers, the development of a socio-technical system can be described based on references (Albers and Rapp 2022). References can be taken from predecessors, competitors, and even industry-external products or research results. Consequently, new system generations are mainly based on proven solution principles with a small inclusion of new designs. The reason for developing based on references with minimal modifications to existing solutions is to reduce risk, technical novelty, and minimize investment (Albers et al. 2015). In the case that the systems in development are perceived as products, the authors refer to PGE - Product Generation Engineering. Albers et al. (2015) defined the model of PGE as the development of product generations through the adaption and new development of subsystems. Reference systems are used as a basis for developing new product generations. There are three types of variation activities for developing a new product generation: while the subsystem adaption is implemented through the carryover variation (CV), the new development occurs through principal variation (PV) and embodiment variation (EV) (Albers et al. 2017). Ropohl (2009) put forward that products and processes were aspects of the same thing and can be seen as system of objectives and their functions. The outcomes or the realization of development paths are applicable across different product generations and can generally be understood as systems (Albers et al. 2022). The model of SGE presupposes a development based on combining the three types of variation from the model of PGE. The embodiment variation (EV) is referred to as attribute variation (AV) in the model of SGE. An AV is used to develop a subsystem of a new system generation, in which the elements and connections within that subsystem are essentially maintained but the characteristics of these are changed. For instance, in the early stages of development, simulations and virtual prototypes can be used, similarly to previous product generations, as references for the development of a new product generation (Albers and Rapp 2022). Figure 1 shows a simplified illustration of the three different types of variation of subsystems of the smart home fire detection system.

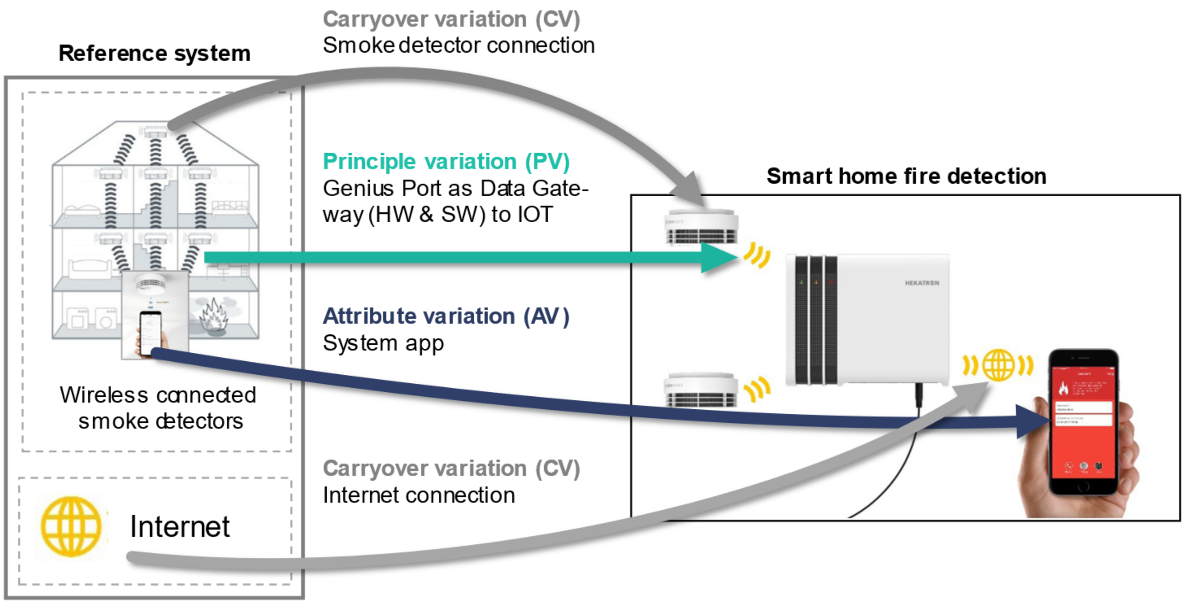

Figure 1. Subsystem of the smart home fire detection system (simplified illustration) Albers and Rapp (2022)

2.3 Digital Platform Business Model and Terminology

In the course of digitalisation and the associated changes, the linear value chain transformed into a complex, highly networked digital platform ecosystem (Jaekel 2017). Due to the transformation, the relationship between the actors changed as well. The digital platform stands out due to its scalability, its ability to tap into new sources of value creation and offerings, and its use of data-based tools, which enable feedback loops in the community (Parker et al. 2017). One of the first digital platform business model definitions stemmed from Bakos (1998), who defined digital platform as an internet-based electronic marketplace and intermediary simplifying the exchange of information, goods, services, and payments. It creates an economic value, increases effectiveness, and reduces transaction costs. A few years later, Drewel et al. (2021) emphasized digital platforms regarding strong network effects and defined the characteristics of a digital platform business model by providing value added interactions. Furthermore, Hasler and Schallmo (2021) concluded based on a citation analysis that digital platforms can essentially be reviewed through two main perspectives: Economy and Technology. Within the economy context, a differentiation was made between (digital) transactions- and (digital) innovation platforms. A (digital) transaction platform focuses on the exchange and a (digital) innovation platform serves as a basis for developments (Hasler and Schallmo 2021). Moser et al. (2019) referred to the digital platform as the link between digital data and innovative business models. In the product development context, a business model can be seen as part of the product (Albers et al. 2020). Gassmann et al. (2014) identified 55 patterns when considering business models. These are essentially distinguished between traditional, product-centric business models and digital, data-centric business models. Relevant, digital platform can be perceived as a driver of a digital business model.

3. Methods

Figure 2 shows the four primary process steps applied in this study. For the systematic literature review (1) various databases such as Google Scholar, ScienceDirect, ResearchGate were screened for existing digital platforms business model definitions, extracting 55 relevant definitions. The definitions were recorded in an Excel spreadsheet and filtered for duplicates and secondary sources. Consecutively, these duplicates and secondary sources were excluded to ensure only primary sources were considered. It resulted in a data set of 32 relevant definitions. The empirical data analysis (2) was carried out using semantic analysis and the IBM SPSS Modeler Text Analytics software (IBM 2021, 2022).

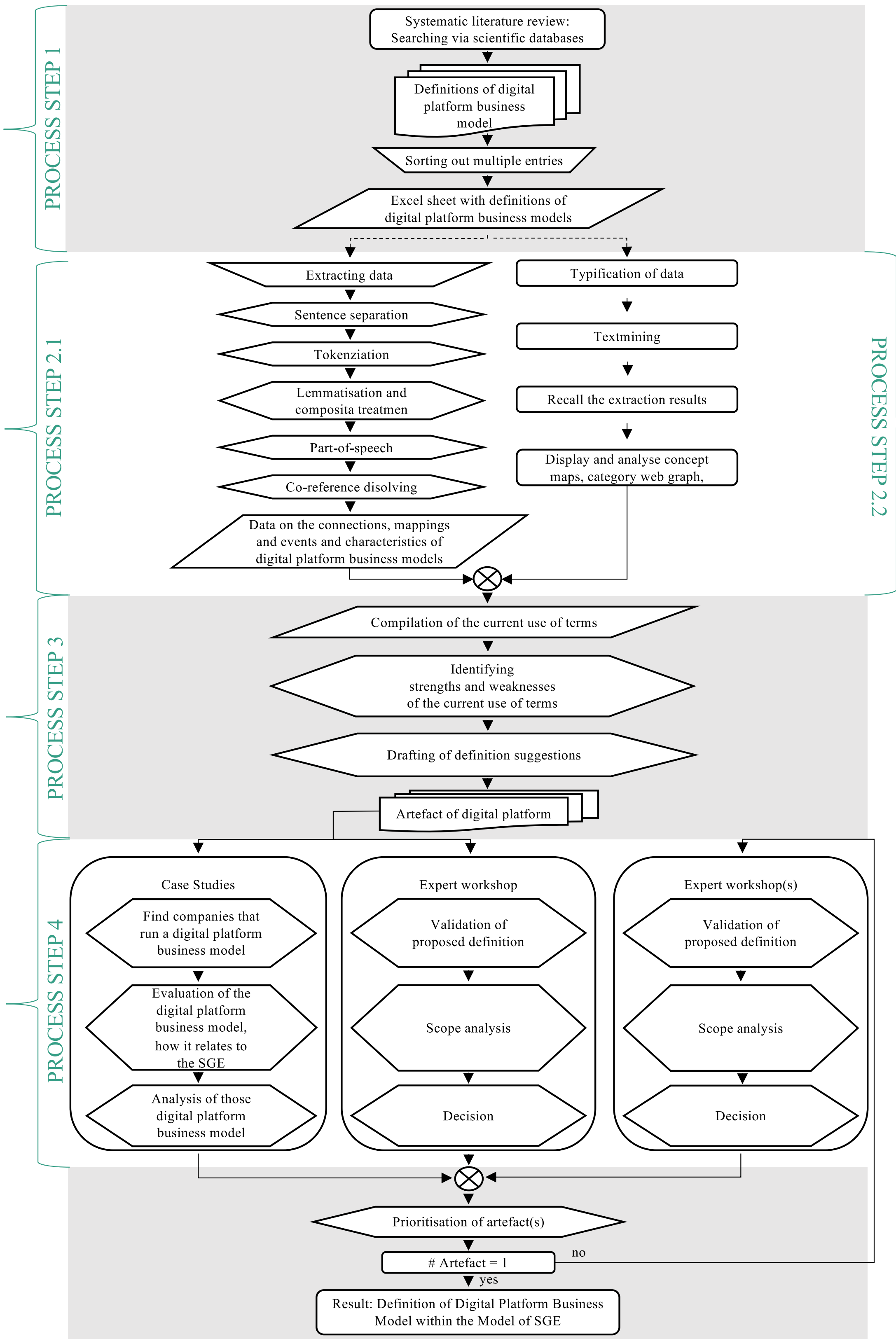

Figure 2. Research Methodology

Applying the software subsequently validated the semantic analysis results. Generally, semantic analysis examines each individual definition from the dataset in detail by extracting information from the data and recognizing data streams and structures (Lenz 2013). Particularly in this study, relationships, associations, elements, and digital platform business model features were extracted through linguistic pattern recognition in the data (Lenz 2013). Prior to parsing text into smaller sentence elements, it is recommended to store information since redundant sentence indices might be deleted by default (resolution) (Meier 1964). In the semantic analysis, the first step divided texts into sentence levels and subsequently into tokens (tokenization) (Meier 1964). Tokens are the smallest units on a single word level. After tokenization, the words were exposed to lemmatization, which transforms words into their morphological root and clusters them accordingly. Thus, the respective definition was broken down to the smallest sentence fraction and examined for meanings, synonyms, linkages, sentence positions (Meier 1964). This process step was performed by the software as part of text mining. In the compilation and definition drafting step (3) various definitions were analysed in more detail to filter different contexts and create the first intermediate artefact of the definition. The artifact's underlying assumption is that digital platforms can essentially be considered from two perspectives, the economic and the technological perspective (Hasler and Schallmo 2021). The economic perspective was adopted by distinguishing between the digital transaction platform and digital innovation platform (Yoffie et al. 2019). After initially creating this artefact, five established companies operating with digital platform business models were analysed in more detail and the definition was subjected to preliminary validation in a workshop and academic discussions. Based on feedback the artefact was further developed into a second intermediate artefact. In the final step validation and refinement (4), the second intermediate artefact underwent rigorous validation in expert workshops. These workshops were designed based on previous studies, specific expertise, and experience. Within the expert workshops, participants intensively discussed the difficulty of defining a digital platform business model in the model of SGE. Conducted in two steps, the primary goal was to integrate and link new aspects, resulting in critically reflecting and validating the intermediate artefact with higher qualitative output. The secondary goal was to further develop the definition.

4. Results

Within the systematic literature analysis, 55 relevant definitions were found; only considering the unique mentions resulted in a data set of 32 definitions. The term digital platform was used as a synonym for digital platform business model, the authors proofed the terms beforehand in the research paper. The individual results were compressed from the software and reproduced in the Figure 3 displayed. The differentiation of the relationship types was considered during compression and reconstruction. As depicted in Figure 3, the SPSS Modeler Text Analytics identified four concepts, namely, *platform*, *digital platform*, *interaction*, and *service*.

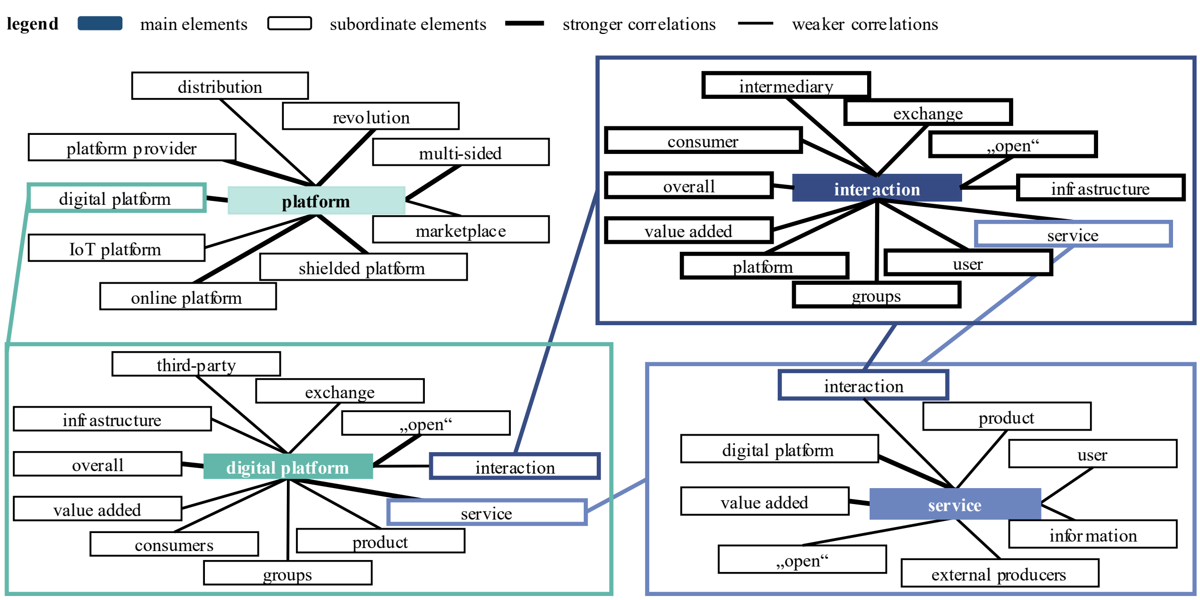

Figure 3. SPSS Text Analytics – concept network diagram

The concept network diagram shows the links within the concepts and the corresponding elements. The line thickness depends on the connection frequency. More precisely, the thicker the line, the more frequently the connection was found in the data sets. *Value added*, *infrastructure*, *exchange, interaction, service, open, third party and groups* were determined as important linking terms regarding the term *digital platform*. The linking terms identified in this context are the terms *intermediary*, *exchange*, *open*, *value added*, *digital platform*, and *infrastructure*. The terms *interaction* and *digital platform* are connected via the term *service*. A category web graph was used to visualise the connections, including the weighting showing their role. The network diagram nodes visualise the relationship between the elements. The relationship strength between the elements is expressed in different line types. The thicker the line, the more strongly are the elements related to each other. The box sizes indicate the frequency regarding the record collections. Elements found less in the definitions compared to the elements mentioned were business, market, groups, and standards. It is worth noting that rules and infrastructure should be in place for a digital platform business model. Likewise, interaction and value added were elementary components of the digital platform business model. Table 1 shows components of a digital platform business model based on the literature. It should be noted the author Parker formulated two definitions that were considered duplicates. Thus, one was omitted from in the enumeration.

Table 1. Components of a digital platform business model based on the literature

characteristics author (32 sources)	exchange	matching	two-/ multi-sided market	value	effectiveness & efficiency	cost reduction	interaction	transaction	innovation	data	intermediary	digital resources	network effects	rules	software	modular design	open architecture	interface
Bakos (1998)	x	x		x	x	x					x							
Biktom (2018)				x		x	x	x	x	x	x							
Baums (2015)			x								x							
Monopolkommission (2015)							x				x							
Larger (2015)			x	x			x				x							
Chen et al. (2021)		x					x	x	x			x						
Drewel et al. (2021)	x	x	x	x	x		x			x	x		x	x				
von Engelhardt et al. (2017)			x		x		x						x					
Evans & Gawer (2016)										x			x					
Gilbert (2020)	x		x	x			x					x						
Toutaoui et al. (2021)							x	x							x			
Dahm & Thode (2019)		x	x													x		
Van Alstyne (2021)	x			x			x							x			x	
Parker et al. (2017)	x	x	x	x			x							x			x	
Rochet & Tirole (2006)			x				x											
Evans & Schmalensee (2016)			x				x											
Wortmann et al. (2019)		x	x		x		x	x		x	x							x
Obermaier et al. (2019)	x	x	x	x	x		x				x			x				
Tiwana (2014)							x								x			x
Europäische Kommission (2015)			x	x			x				x							
Moazed & Johnson (2016)	x		x	x			x				x							
Choudary et al.	x	x		x														
Hagiu & Wright (2015)			x				x	x					x					
Hein et al. (2019)			x	x							x					x		
Jackel et al. (2020)							x						x					x
Pauli et al. (2021)					x		x			x								
Täuscher & Laudien (2018)							x	x										
Porsche Consulting (2022)			x	x				x										
BDI (2018)		x	x				x				x	x						
Ruver et al. (2018)			x	x														
Redweik et al. (2012)			x		x						x							
correspondences	**8**	**9**	**19**	**14**	7	2	**22**	7	2	5	**13**	3	5	4	2	2	2	3

Ultimately, the digital platform business model definition in the model of SGE for CPS was iteratively developed through expert workshops. The gained knowledge from the workshops was summarized in the following paragraphs.

Results of expert workshop (1):

One initial finding was digital platforms can be viewed from two main perspectives - economy and technology. This research focused on the economic viewpoint. Considering the case studies, workshop results, and the definition of an innovation platform, a digital platform business model in the model of SGE applied as the next genus due to its innovative nature and interaction between the systems and the digital platform. In this context, a digital transaction platform, more precisely a marketplace, had no influence, while an innovation platform directly influenced the system. It was also evident in the digital platforms existing in practice. At this point, the understanding of innovation did not include the component of market penetration. Another finding regarded the actors of a digital platform business model. The actors in the model of SGE may differ depending on the branch, usage, and company. Therefore, the term "entities" was chosen in the definition, wherein the sentence fragment "networks" was included from the intermediate artifact. Lastly, the experts discussed the need for an open, neutral interface and flexible, compatible components in detail during the workshop. Essentially, an open and neutral interface can ensure a linking point for third parties and other components within the company. Thus, the following should be mentioned: Based on the assumption that the globalization and internationalization of companies will continue, the open and neutral interface should be an essential aspect in a digital platform business model. Interfaces enable linking and associated cooperation and collaboration, which can be made more effective using a neutral and open interface. The flexible and compatible components observing the networking character of a digital platform business model are another imperative aspect concerning innovation and the further development of systems and the company.

<u>Results of expert workshop (2):</u>
In this workshop, the experts named the term "digital platform business model" as a definiendum. The next category term was defined as "business model pattern" as the genus proximum regarding to the 55 pattern cards from (Gassmann et al. 2014) and the "business pattern terminology" of Osterwalder and Pigneur (2010). The experts concluded the digital platform business model in the model of SGE facilitates substantially new value added by integrating entities in form of providers, customers, users, and partners as well as the CPS. The definition of a digital platform business model in SGE for cyber-physical systems is shown in Figure 4:

> A **digital platform business model** in the model of **SGE – System Generation Engineering** according to ALBERS is a **business model pattern**, that facilitates **substantially new value added** through a **multisided market** by integrating entities in form of **providers, customers, users,** and **partners** as well as the **cyber-physical system**.
>
> The digital platform business model poses as an intermediary with its **open and/or closed infrastructure** as an **interface** between the **flexible** and **compatible networking components**. An essential basic key criteria is **data integration** between the cyber-physical system and the digital platform business model that creates a **trustworthy** and **economic value added** through **benefit** from provider, customer, user, and partner. A central characteristic are **network effects** promoting digital platform business model scaling. If implemented successfully, the continuous and adaptively gained information sourced through the **newly established data network** will affect the **future robust** and **strategic system planning** and **product portfolio management**.

Figure 4. Definition of a digital platform business model

The entity of "partner" was discussed; the experts used the common definition of Osterwalder and Pigneur (2010) to holistically describe this entity. Osterwalder and Pigneur (2010) used the term "key partnerships" to describe the network of suppliers and partners that make the business model work. The business model can be optimised by alliances to reduce risk or acquire resources. The authors distinguish between four partnerships: (1) strategic alliances between non-competitors, (2) coopetition, a strategic partnership between competitors, (3) joint ventures to develop new business, and (4) buyer-supplier relationship to assure reliable supplies (Osterwalder and Pigneur 2010). To illustrate the entity of a partner in developing a digital platform business model in the model of SGE, the experts define a (key) partner as an entity that makes the business model work. In the development of a CPS, a partner can be an IT partner hosting the data; without these partners the business model will not work. The term "two-sided market" was not explicitly mentioned as it is a subset of the larger concept of a multisided market. Additionally, the term "open or closed infrastructure" was expanded to "open and/or closed infrastructure", which becomes clear when comparing the digital platform business models of Google with the ones of Apple Inc. Regarding the hardware side, Apple Inc.

restricts the use of iOS to its proprietary smartphones exclusively, indicating a closed infrastructure model. Google's Android, on the other hand, works on various smartphones with minimal requirements, therefore indicating an open infrastructure model. Still both Apple Inc.'s App Store and Google's Play Store, serving as mobile app stores in an open infrastructure model, allowing developers to distribute their own apps. However, it's noteworthy that Apple Inc. enforces much harsher quality standards than Google. To this end, Apple Inc. can serve as an example of an open and/or closed infrastructure. During the workshop, the following characteristics of a digital platform business model were identified in the model of SGE: Supporting data interaction and strategic product and platform planning, and interaction between the actors on the digital platform business model. Based on the expert workshops and the resulting aspects of a digital platform, a definition of a digital platform business model in the model of SGE for cyber-physical systems was created.

5. Discussion

A digital platform business model in the model of SGE – System Generation Engineering is defined as a business model pattern that can be subordinated to the business model pattern concept. The digital platform business model differs from its interaction with cyber-physical systems, the integration of entities, and the newly created data network and facilitates substantially value added. Regarding the data set evaluation using the frequency parameter, there was no explanation for correlations between the obtained results when performing the SPSS Modeler Text Analytics. Furthermore, the result quality depended on the dataset text quality. The existing definitions from the literature review and semantic analysis did not include the interaction with hardware products such as CPS. One assumption can be that the definitions related primarily to marketplaces and not to the product development perspective. The entities identified on a digital platform business model in the model of SGE revolve around four different role types, namely, providers, customers, users, and partners. Considering digital platforms generate value added, the objective is to generate this through provider, customer, user, and partner benefits. The experts unanimously agreed that the focus must be on benefitting all entities. A uniform definition of the digital platform business model in the model of SGE is particularly crucial for shaping a productive discussion about developing and elaborating on business model patterns.

6. Conclusion

Utilizing a general definition is necessary for scientifically and practically oriented discussions. The heterogenic definitions for digital platform business models, as identified in this systematic literature analysis, underscores the complexity and challenges in the domain of digital platform business models interfacing with cyber-physical systems. A lack of a unified understanding could lead to missed opportunities since developing effective business models or strategies could become an elusive goal and a bottleneck stifling innovation. Thus, this research proposes a definition for the digital platform business model in the context of the model of SGE – System Generation Engineering. The authors identified a digital platform business model in the model of SGE according to Albers as a business model pattern that integrates various entities and the CPS, creating substantial value added in a multisided market. Consequently, this research contributes fundamentally to the discourse on digital platform business models, laying a groundwork for future research and practical applications.

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Biographies

Albert Albers has been Professor and Head of IPEK – Institute of Product Engineering at the Karlsruhe Institute of Technology (KIT) since 1996. He obtained his doctorate degree in 1987 under Prof. Paland at the Institute of Machine Elements and Engineering Design. Before Prof. Albers started his position in Karlsruhe he served as Head of the Development Department and as deputy member of the Executive Board. He is a founding member and chairman of the Scientific Association for Product Engineering (WiGeP) and a member of the National Academy of Science and Engineering (acatech). Since 2008 he is president of the Allgemeiner Fakultätentag (AFT e. V.), the German General Faculty Association. From 2012 to 2015 Prof. Albers was the spokesman and review board member of the DFG Review-Board 402 (Mechanics and Constructive Mechanical Engineering). Along with his commitment to the Association of German Engineers, he serves on Advisory Boards of a number of companies. For his excellent accomplishments and expertise in science, research and education in technical and scientific areas, he and the IPEK-Team received the Honorary Award 2016 of the Schaeffler FAG Foundation. Prof. Albers' fundamental research philosophy is the simultaneous research on methods and processes of product engineering combined with the research on synthesis and validation of new technical systems whilst taking into account the significant role of the engineer within the product development process. Only this combination of research on systems, methods and processes enables a validation of the new development methods and processes immediately during projects of system research.

Carsten H. Hahn is a director of research and innovation at SAP and additionally holds a professorship for Innovation and Entrepreneurship at the Karlsruhe University of Applied Sciences. After studying business informatics at the University of Mannheim and doing his doctorate in Marketing at University Mainz, he began his career as an assistant to the executive board of SAP. Carsten serves as a visiting lecturer at the Sloan School of Management at the Massachusetts Institute of Technology. In his academic work, he founded the [x]Lab, which deals with entrepreneurship and innovation concepts in research, teaching, and practical application.

Patrick Brecht started working as a research group leader of [x]Lab at the Institute of Applied Sciences (IAF) at the Karlsruhe University of Applied Sciences after he completed his study in industrial engineering. As a research associate he focuses on innovation processes, methods, and digital platform business model development. For his doctoral research at IPEK - Institute of Product Engineering at the Karlsruhe Institute of Technology (KIT), he works in the research group Design Methods and Design Management. Within his work, he develops a method to develop digital B2B Platform Business Models in the model of SGE – System Generation Engineering.

Ümüs Cetinkaya successfully completed her studies at the Karlsruhe University of Applied Sciences in international management. In her work as a research assistant, she focuses on new business models tailored to the needs of small and medium-sized enterprises, addressing the challenges posed by digitalization and exploration. Currently, she holds a position within a mid-sized IT software company, where she actively supports clients in the manufacturing sector in their digital transformation endeavors. Her primary emphasis lies in introducing integration platforms into manufacturing companies.

Felix Pfaff was a research associate at the IPEK - Institute of Product Engineering at the Karlsruhe Institute of Technology (KIT) with a focus on innovation processes and methods after he completed his study in mechanical engineering in 2020. He has been working as a research group leader of the research group Design Methods and Design Management since 2022. Within his work, he analyses the evolution of mechatronic systems with the model of SGE – System Generation Engineering to gain insights into the relationships between innovation success, changing contextual factors and variation activities.

Michael Schlegel has been a research associate at IPEK - Institute for Product Engineering at the Karlsruhe Institute of Technology (KIT) since 2021, focusing on innovation processes and methods. He coordinates the research field PGE - Product Generation Development and is responsible for Mechanical Design IV. In his dissertation, he deals with the future-robust further development of products and product portfolios based on the model of SGE - System Generation Engineering.

Maximilian Fischer has been a research associate at IPEK - Institute for Product Engineering at the Karlsruhe Institute of Technology (KIT) since 2022. Within his work as well as his dissertation, he focuses on the identification and development of methods and tools, supporting the integrated development of products and their associated production systems within the framework of product-production-codesign.