Requirement Engineering in the Age of System and Product Complexity – A Literature Review

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***Abstract*—Product, service, and system development can be approached with numerous processes and methodologies. Many of these models begin with the definition of requirements to fulfill. Thus, these requirements outline the purpose of the development and design. Due to the inherent attribute of the requirement definition and the product development process, the aspects to design are usually defined in the beginning, and subsequently implemented or realized. This time difference between the definition and the actual realization of the requirements creates a high potential for uncertainty and risk, which is especially critical when it comes to emergent behaviors and complexity of the product or system. Based on the connection between requirements and complexity, the presented research set out to define and assess the current state of the research in the form of a comprehensive literature review, to serve as a basis for further research. This review includes the topics of general complexity, requirement engineering, and system/product complexity. The literature showed ongoing and active research for both fields with a longer history for complexity. Since it was first mentioned in 1948, complexity has expanded its application and research to various engineering domains which were identified based on cross connections. Requirement engineering showed its origins in computer science/engineering, and successive expansion into other domains, such as mechanical engineering. Both fields, the one for complexity and requirement engineering, also show recent trends, such as the application and inclusion of AI and Machine Learning, Agile, and certain security/resilience foci. All in all, a comprehensive overview for the topics is provided with insights into expansion and evolution.**

Keywords*—requirements, complexity, product development, requirements engineering, systems engineering, emergence, risk

I. Introduction

When it comes to product development and design, a multitude of factors play a role all throughout the various steps of the process. Regardless of the field or area, a product or service is developed to fulfill a certain purpose and or solve problems in a broader sense [1]. In order to solve such a problem and fulfill the purpose over the life cycle of the system, the development can be approached in various ways and with different methodologies. Popular models include, but are not limited to the Waterfall Model [2, 3], Stage-Gate Model [4] (see Figure 1), and V-Model [5]. In these models, early in the development process, the aspects to fulfill with the product and its design are defined. This happens in the first three phases of the Waterfall Model or, as depicted in Fig. 1, in the second stage of the Stage-Gate Model.

These early phases set the requirements which the system to develop must fulfill. Thus, the requirements outline the objectives of the development as well as the design and are directly related to the purpose and problem described above. Hence, despite the early phases and steps only representing one part of the product life cycle, they define and influence a substantial portion of the features, and as a result have a disproportionate influence on the entire development process.

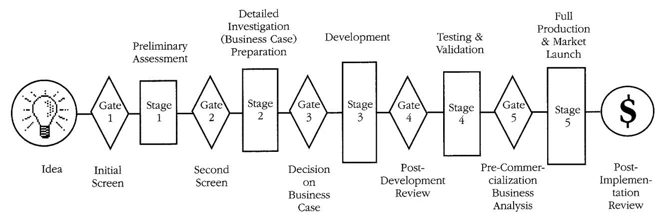

Fig. 1. An Overview of a Stage-Gate System [4]

Due to these disproportionate influences of requirements in the development process, their elicitation and definition is critical as changes downstream can have detrimental effects and significant drawbacks, such as immense costs. Therefore, even a management discipline for changes and their implementation exists [6-8]. Yet, the definition of requirements must be considered speculative to some extent as they are defined before anything has been developed at all. For example, it is possible, and not even unlikely, that the requirements defined at the beginning of a development process will not be entirely appropriate anymore once the development is concluded. Such a loss of applicability and appropriateness can result from changes in stakeholder views or demands. Furthermore, the actual outcome of the development process depends on factors that can change over time, such as new technologies or market changes [9].

In addition to the described circumstances, product complexity and behavioral dynamics are additional factors that originate from requirements. Since product complexity can emerge in unforeseeable ways, it is difficult to account for, especially at the beginning of the development.

All these circumstances create a dynamic within the development that might show potentially unwanted behaviors at times. This can be due to complexity, erroneous or inappropriate requirements, or a culmination of both. In some cases, emergent behaviors can be outright dangerous. For example, the Galaxy Note 7 smartphone, which Samsung released in 2016, was subject to faulty batteries due to design flaws and manufacturing defects [10, 11]. These aspects eventually lead to the recall of the product entirely, which illustrates the potentially grave effects and threats to the fulfillment of the product purpose, and thus to the success of the entire development. These potentially unwanted outcomes make an effective management of complexity and the requirements critical.

The described examples show a connection of requirements and complexity. Thus, to understand both topics from a scientific perspective and how they collide, a literature review was conducted to outline the current state, as well as history. The results of this review are presented and cover complexity in general, requirements engineering, and system/product complexity.

II. Literature Review and Research

Since the topics described in the introduction penetrate various scientific fields, their overall state was assessed in a structured fashion to allow for a holistic assessment. Thus, the following parts address general complexity first, starting with its origins. Subsequently, requirement engineering is evaluated from a general perspective before outlining system and product complexity specifically as a topic that conflates both areas.

A. General Complexity

To conduct the literature review, the research of complexity in a general fashion was structured to look at complexity measures and their application, as this allows for the most efficient elicitation of the information regarding the other two topics. This structure is necessary because not all complexity research is applicable to the fields at hand. Thus, to assess complexity, regardless of the exact interpretation or scientific field, a metric to apply is necessary. The following paragraphs show the evolution of the complexity science.

First, when it comes to the term complexity, it is important to understand its utilization in various domains [12] as it is used with various interpretations [13], sometimes even synonyms, in the media, for instance [14]. Moreover, complexity has been described as "difficult to formulate [15]. Due to this ambiguity, the following focuses, for the extent of this literature review, on the complexity science area for the theoretical part, and includes other domains for the actual metrics. This allows for the exclusion of specific interpretation of the theoretical foundation, but simultaneously includes adaptations that are application related.

In general, complexity was first mentioned by Weaver in 1948 [16] and over time has led to the development of complexity science [17]. This science deals with the characteristics of complex systems that can be, but are not limited to, emergent behavior due to reciprocities of system elements [18], nonlinear and dynamic interactions of elements [19], and bilaterally dependent relations of elements [20].

Weaver [16] described two kinds of complexity: organized and disorganized complexity. The first category, organized complexity, is characterized by a substantial number of variables and "factors which are interrelated into an organic whole" [16]. These factors all must be considered when the whole system is being analyzed. Problems of organized complexity differ from the ones pertaining to simplicity as they exceed small numbers of a few variables. On the other hand, their number is still relevant, which distinguishes it from the second category. Disorganized complexity is characterized by an abundance of variables in a system. Each variable exhibits individual behavior, which is described by Weaver as "erratic, or perhaps totally unknown" [16]. Despite all these individual influences, disorganized complexity tries to explain the behavior of the system in its totality, and therefore allows the analysis despite all the underlying variables. Such analyses are related to statistical techniques, which become applicable once individual behavior gives way to average behavior(s) to be assessed.

With the above listed attributes, general complexity in systems and products is linked to the concept of emergence [21], which occurs when an "increasing number of independent variables begin interacting in interdependent and unpredictable ways" [22]. This description also distinguishes a complex system from a complicated one. In a complicated system, the interactions and the behavior of a system can be tracked to concerned components, whereas in a complex system, the outside behavior is defined by the interactions, and specific tracking becomes impossible [23]. This dependence on interactions and bilateral connections also prohibits decomposition of the system into smaller, still functionally equivalent sub-systems [24, 25]. With these criteria and foundation, general complexity metrics were researched.

To characterize and structure the research, the metrics were classified and assigned to different engineering/science fields. This allows for a simplified differentiation and can furthermore foster the transfer of other concepts from and to those fields. The assigned fields were derived from general domains of engineering in relation to systems [26, 27]. Based on the application of systems engineering, various publications describe the main branches to consider as civil, mechanical, electrical, and chemical engineering [28]. These are in accordance with the first edition of the Oxford Handbook of Interdisciplinarity [29], which solely adds industrial engineers as a fifth branch. In the most recent edition though, more diversity can be found, and the following branches are listed as engineering fields: civil, mechanical, chemical, electrical, electronic, industrial, nuclear, computer, biological, and nano [30]. This is due to sub-division over the years as described by Dandy [31]. Since the research is based on engineered systems, the systems side also adds possible domains.

From a wording perspective, the term system brings up the area of Systems Engineering (SE). Despite the term engineering in SE, it does not necessarily apply to the definitions [26, 27] and is considered a "transdisciplinary and integrative approach to enable the successful realization, use, and retirement of engineered systems" [32].

When looking at the fields connected to SE besides the engineering areas already covered above, it becomes clear that SE is connected to many domains [33, 34] and Kossiakoff et al. even describe those domains as expanding [33]. This might be because SE can generally be applied to many areas if the area "develops critical and logical thinking" [35]. General categories have been defined and include the domains for management, engineering, technical, political & legal, human, and social [33].

Still, due to the abundance of different complexity measures and research across the fields and areas mentioned in the paragraphs above, it would be impractical to attempt listing every single relevant publication and work in existence. For example, the conjunct search terms “chemical engineering” and “complexity” yielded over 1.5 million results on Google Scholar (as of February 2020), and “industrial engineering” in conjunction with “complexity” over 2.5 million results. Thus, a structured approach was applied that used citation counts as of February 2020, as a measure for the publications. Based on this approach, the most cited publications regarding the term and metric of complexity were searched in a first step. In a second step, the publications citing these works were considered based on the search terms in conjunction. To define which publications are popular enough, a hard cut-off was chosen at a citation count of 250. This reduced the resulting lists to a reasonable amount and allowed the extraction of popular approaches. The process was then repeated iteratively for each discovered publication to create a network of citations based on popularity. Since citation count can increase over time, the possibility remained that recent publications exist which might be eliminated by the 250-count due to their lack of age, despite being important and applicable. Thus, a subsequent round was conducted only for the time between 2010 and 2020 with all the parameters above, but a citation count limit of 100.

The above-described approach for the literature research was repeated for the perspective of the engineering fields and systems engineering. Furthermore, the connections between the different publications were assessed by linking them to each other via cross-references, and based on the described analyses, a final evaluation was conducted to derive a comprehensive structure. This includes a general overall map based on all the mentioned aspects and approaches, as well as their connections. The classifications connect the overall structure and show the interfaces. The map could then be used to assess the different fields deduced and defined above, leaving them with a set of publications utilized to differentiate the fields.

When looking for complexity metrics, one of the first and most cited publications is Shannon’s “Mathematical Theory of Communication”, which is a fundamental work of complexity research regarding entropy [36]. Shannon explains that the entropy of a system describes the set of probabilities said system has regarding its state. Therefore, a metric based on the described entropy is possible. Albeit not necessarily directly related to any field, Shannon’s research is based on communication and signal processing.

Another notable publication, if not the most popular one, is McCabe’s 1976 paper in which the author describes his graph-theoretic complexity measure [37]. In said publication, the author outlines the connection of graph-theory concepts and complexity, and connects them to the structure of computer programs, as well as their development. Based on this association, the research belongs to the computer science field.

The third and last popular publication, linked to over 8000 (as of February 2020) other publication according to Google Scholar, is Kauffman’s 1996 book “At Home in the Universe” [38]. In this book, Kauffman describes and explains self-organized complexity and relates it to biological structures.

Based on these three starting points, other publications were connected based on the two citation count limits, and every publication was assigned to one of the fields below. This yielded a map and overview, showing the pervasion of the complexity measures into the different fields: Signal and Information (Info) Complexity (Electrical Engineering), Physical Complexity (Chemical, Nuclear, and Nano Engineering), Infrastructure and Network Complexity (Civil, Industrial, and Electrical Engineering), Biochemical Complexity, Design & Manufacturing Complexity (Industrial, Mechanical, and in part Electrical Engineering), Software (SW) and Code Complexity (Computer Engineering). All these areas show significant research and metrics for complexity. Furthermore, the defined engineering fields outlined in the previous chapter can directly be sorted into each of the categories but overlap exists.

The discovered research publications are listed in Table 1. Herein, over 30 publications are included that pertain to complexity measures. All references were mapped out and yielded the fields listed in the previous paragraph. With the overview of the references, their connections yielded the map depicted in Figure 2. Some publications possibly touched various fields, but in general, these areas were discernible with the locations and adjacencies shown.

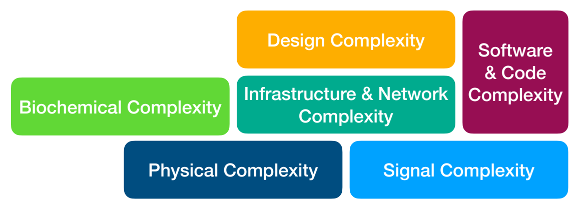

Fig. 2. Complexity Areas and Scientific Fields [36-67]

Following the general complexity measures, a specific look at requirement engineering (RE), product/system design & development complexity was conducted. This separation also allowed for a more detailed assessment of the following state of the research compared to the general complexity macro view that would have potentially been partially redundant. Therefore, the following sub-section will address the state of the research regarding RE, before moving to product/system complexity.

B. Requirement Engineering

For RE in general, publications can be found as early as the 1960s [68] in Software Engineering [69]. The term requirement dates to the 19th century [70]. In the 1960s, military standards close to RE were developed [71]. Yet, the widespread use of the term RE as a professional discipline did not occur until the end of the 20th century [72]. This is underlined by the scarcity of publications before the last decade of the 20th century. For instance, limiting the time frame to the period before the standards leaves few publications with more than 10 citations (as of November 2020) that can be considered popular.

The first popular contribution comes from Alford et al. who developed the Software Requirements Engineering Methodology (SREM) [73] in 1977. SREM was designed for software and weapons systems and addresses activities from the generation to the validation of requirements. The methodology relies on collected data and system functions allocated to the respective processor. Overall, the SREM covers requirement management. Yet, the methodology was still geared towards software and limited due to its reliance on data and underlying assumptions. Alford et al. expanded the approach later [74, 75].

Between the work of Alford et al. and the emergence of the first standards in the 1990s, only remotely related publications can be discovered. For example, IEEE published a "Standard Glossary of Software Engineering Terminology" [76] in 1983 that included requirements. In addition, other approaches can be considered RE methodologies, despite not being associated with RE at their inception. Such approaches could be the Waterfall Model by Boehm (mentioned in Section I), which is further underlined by various other publications of Boehm addressing requirements [77]. Overall, until standards were established, no major publications related to the topic of RE were found. Thus, the next paragraph will begin with the explanation of these standards that also coincided with the inception of related journals, such as the Requirements Engineering Journal [78].

Towards the end of the 20th century, now popular approaches emerged [79, 80]. Moreover, in 2011, an international standard was created [81]. In this summarized standard, based on various other ones, RE is defined as "an interdisciplinary function that mediates between the domains of the acquirer and supplier to establish and maintain the requirements to be met by the system, software or service […]". RE is supposed to facilitate an understanding and provide a verification basis [81]. Also, the standard defines requirements as statements that "translate or express a need and its associated constraints and conditions" [81]. These needs stem from the stakeholders of the product. In addition, the acquisition, derivation, and formulation of the requirements must comply with standard characteristics. Overall, the standard provides a uniform framework for RE and includes process details.

Concurrently with the inception of the standards and conferences, such as the "International Requirements Engineering Conference" by IEEE [72], RE expanded and was taken into consideration in other business fields. Such fields included engineering design in a general sense [82, 83], mechanical engineering [84], and management [85]. With this expansion, RE became widely adopted and can now be found in fields where products are developed, such as car design [1].

Despite the expansion and wide-spread application of RE, the underlying processes and structures are still shared by most fields and have only been adapted due to different circumstances of the respective field. The expansion of RE exposed the concepts and processes to various other fields. As of the year of this writing (2021), requirements engineering is still evolving and being applied/evaluated in new fields (also see Section III).

Regarding the most recent developments, numerous publications of the last five years address issues with agile development and RE [86-98]. Further trends can be seen in the research of the application of data analyses, and other processing tools to support the RE processes [88, 99-104], as well as an upcoming focus on security of systems and resilience [105-111]. Lastly, the extensive work by Wagner et al. shall be mentioned here, who recently conducted an extensive and international survey regarding the current application of RE [112].

TABLE I. Complexity Areas & Scientific Fields References

#	*Author(s)*	*Title*	*Area*
[38]	S. A. Kauffman	At Home in the Universe	Biochemical Complexity
[50]	C. Adami et al.	Evolution of biological complexity	Biochemical Complexity
[52]	D. W. McShea	The hierarchical structure of organisms	Biochemical Complexity
[53]	P. Romero et al.	Sequence complexity of disordered protein	Biochemical Complexity
[58]	D. Bonchev D. H. Rouvray	Complexity in Chemistry, Biology, and Ecology	Biochemical Complexity
[59]	R. M. Hazen et al.	Functional information and the emergence of bio-complexity	Biochemical Complexity
[65]	C. P. Panos et al.	Atomic Statistical Complexity	Biochemical Complexity
[40]	P. R. Bryant	The order of complexity of electrical networks	Design Complexity
[49]	H. A. Bashir V. Thomson	Estimating Design Complexity	Design Complexity
[51]	C. Eun Sook et al.	Component metrics to measure component quality	Design Complexity
[56]	R. Subramanyam M. S. Krishnan	Empirical analysis of CK metrics […]	Design Complexity
[57]	H. A. Bashir V. Thomson	Estimating design effort	Design Complexity
[61]	C. C. Bozarth et al.	The impact of supply chain complexity on manufac-turing plant performance	Design Complexity
[63]	F. Isik	An entropy-based approach for measuring complexity in supply chains	Design Complexity
[64]	J. D. Summers J. J. Shah	Mechanical Engineering Design Complexity Metrics	Design Complexity
[66]	W. ElMaraghy et al.	Complexity in engineering design and manufacturing	Design Complexity
[39]	J. Portugali et al.	Complexity Theories of Cities Have Come of Age	Network Complexity
[54]	S. H. Strogatz	Exploring complex networks	Network Complexity
[43]	S. Lloyd H. Pagels	Complexity as thermodynamic depth	Physical Complexity
[45]	M. Gell-Mann S. Lloyd	Information measures, effective complexity, […]	Physical Complexity
[36]	C. E. Shannon	A mathematical theory of communication	Signal & Info Complexity
[41]	H. A. Simon	The Architecture of Complexity	Signal & Info Complexity
[46]	J. H. Holland	Hidden Order	Signal & Info Complexity
[55]	J. M. Carlson J. Doyle	Complexity and robustness	Signal & Info Complexity
[37]	T. J. McCabe	A Complexity Measure	SW & Code Complexity
[42]	E. J. Weyuker	Evaluating software complexity measures	SW & Code Complexity
[44]	S. R. Chidamber C. F. Kemerer	A metrics suite for object oriented design	SW & Code Complexity
[47]	V. R. Basili et al.	A validation of object-oriented design metrics […]	SW & Code Complexity
[48]	C. Collberg et al.	A Taxonomy of Obfuscating Transformations	SW & Code Complexity
[60]	A. E. Hassan	Predicting faults using the complexity of code changes	SW & Code Complexity
[62]	J. P. Crutchfield K. Wiesner	Simplicity and Complexity	SW & Code Complexity
[67]	N. Fenton and J. Bieman	Software Metrics: A Rigorous and Practical Approach	SW & Code Complexity

When it comes to requirements engineering directly in connection with product complexity, there has been no recent trends or publications in the last five years. Overall, the relevant publications are scarce as most topics situated in the RE domain address complexity as a phenomenon to manage [113, 114].

Figure 3 shows a timeline with the mentioned publications as well as an overview of the areas and foci within RE.

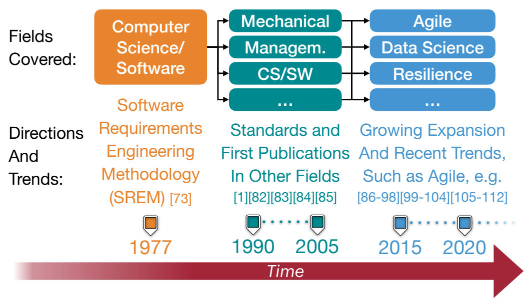

Fig. 3. Timeline and Overview of the RE research history

C. *Product and System Complexity*

When researching product complexity, more publications can be found than for requirements engineering. This is, at least in part, since product complexity is subject to a higher degree of interpretation compared to RE. Whereas standards exist in RE, product complexity is interpreted differently in individual fields and by various researchers [115]. For example, Baldwin and Clark describe complexity in product design as proportional to design decisions [116], Griffin describes it as the number of functions in a product [117, 118], and other authors define it as the number of individual parts in a product/system [119, 120]. Moreover, in fields like project management or supply chain, more interpretations exist [115, 121].

With this abundance of different interpretations, the literature research regarding product complexity becomes complicated as an inclusion of the different adaptations would not be feasible. In addition, utilizing a set definition for product complexity based on the literature review would potentially limit characteristics. Thus, it was decided to not chose a set definition to retain all options for the literature review. The following paragraphs outline the most important works regarding product development in relation to complexity.

A look at the literature regarding complexity in product development shows that the term complexity was diversified according to specific parts of the development process or the product/system. Göpfert [122] described in 1998 that product development complexity showed two facets: technical complexity and organizational complexity. Göpfert stresses though that these two types of complexity cannot be seen as separate, they influence each other, and must be considered together to handle them appropriately [122]. This bisectional partition is also found in other, not product development related fields [123], which the next approach also relates to.

In 2005, Weber proposed an approach like the previous one. Weber's complexity interpretation included five dimensions that are directly related to strategic components [124]: numerical, relational/structural, variational, disciplinary, and organizational complexity. In addition to defining the dimensions, Weber also divided them into two overarching groups: the product/system category, which encompasses the first three dimensions, and the process category, which includes the last two dimensions. Like Göpfert [122] Weber distinguishes between the product related complexity dimensions and the organizational aspects [125].

In 1998, Braha and Maimon addressed design complexity and described two categories [126]: structural complexity and functional complexity. The former describes the complexity related to the representation of information; the latter outlines complexity regarding the notion behind information, regardless of represented. Thus, functions can be independent from elements, but structural aspects relate to elements.

In 2009, Lindemann et al. [113] proposed a different "structural complexity" approach unrelated to the ones above. The term "structural complexity" by Lindemann et al. is not solely related to spatial structure, as described in other fields [86]; the term relates to all "dependencies within the elements in technical systems" which form structures and cause complexity [76]. As for influencing factors, the authors describe four major fields that shape and form the structural aspects and therefore also impact the complexity: Market, Product, Organizational, and Process Complexity

All the above listed interpretations show that there are various ways to approach the complexity in product development. All four of the mentioned publications outline three key aspects: First, the complexity of the product is connected to, but separate from the complexity of the development process and organizational aspects. Second, complexity can exist within the functions of a product, but also within structure. Lastly, other factors can influence the product design and development complexity.

With the described conclusions, the following dimensions for complexity were derived:

I. **Functional Complexity** is caused by functions that are not related to a component, but describe purpose, notion, and actions; similar to dynamic complexity [127, 128].

II. **Structural Complexity** results from the dependencies, connections, and interactions of product components.

III. **Organizational/Process Complexity** represents the complexity originating from the process and organization.

These three dimensions are visualized in Figure 4. Herein, the organization and process are depicted as the overarching construct for the actual product structure and functions. The latter two directly interact as the functions of the product imply the elements and components, which facilitate functions.

Recent publications in the field of product complexity show a few major trends. First, the most recent work of Sinha [128-130] shows complexity analyses of modular systems and the application of approaches, such as Pareto-Optimization [128] and System Clustering Algorithms [130] to the issue of structural complexity and product architecture regarding modularity. Sinha claims that with the proposed framework [128] "complex systems can be optimized for degree of modularity, while variation of structural complexity […] minimized" [128].

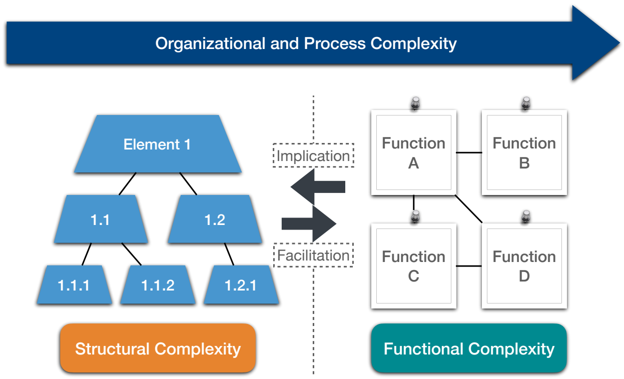

Fig. 4. Dimensions of Product Design and Development Complexity

Sinha also stresses the lack of quantifiability of product complexity in the design phase [128]. Overall, these publications, while in lines with RE, target the early design phase after the requirement and even the function definition.

Second, another trend seen is the application of various neoteric algorithms and tools to model complexity dimensions. Examples for these approaches include for example agent-based modeling [131], statistical methods [132, 133], mechanism-based equifinal causal relations evaluation [134].

Third, recent publications tackled the topics of new product development influenced by complexity. These publications [131, 134-138] apply novel approaches and research results to the complexity of product development to manage or predict the success of new products. They address the whole development process, but assessed cases begin with the design phase when requirements are transformed into design specifications [131].

Fourth, the last trend is less related to complexity itself, but nevertheless connected to it: sustainability. Multiple publications by different authors [139-141] were found that addressed sustainability and its implications regarding complexity. While these research publications do not necessarily directly contribute to the topic of product/system complexity, they add a new factor to considered as sustainability can cause major disruptions within the complexity dimensions.

III. Conclusion

Since requirements in the development process can be linked to emergent behaviors of the final system, a connection between the requirement engineering and complexity exists. Based on this connection, the presented work looked at the topics of complexity, requirement engineering, and product complexity, by providing a literature review for these three fields.

For complexity in general, the literature discovered the origins published by Weaver [16] and subsequently deduced all areas of engineering in which the concept of complexity is currently being applied/utilized. These areas yielded the fields of Design, Biochemical, Infrastructure & Network, SW & Code, Physical, and Signal Complexity. In each area, metrics for complexity were found, framing the overall field.

For RE, the origins in software were outlined, followed by its expansion into other domains and the derivation of standards that unify the elicitation and management. Furthermore, current trends were discovered, such as Agile, resilience, and AI.

Lastly, for the field of product complexity, the different approaches and structures were outlined. This allowed for a comprehensive overview and the elicitation of trends. These trends were partially like RE and included AI, sustainability, and innovation management.

In conclusion, while there is overlap between RE and system complexity, no prospective consideration of the latter has been published and therefore, the inclusion of complexity in the development process remains difficult. This difficulty could be addressed by a combinatory approach, which is in development, based on the insights above.

References

[1] J. Ponn and U. Lindemann, *Konzeptentwicklung und Gestaltung technischer Produkte*, 2nd ed. Berlin Heidelberg, Germany: Springer-Verlag (in German), 2011.

[2] W. W. Royce, "Managing the Development of Large Software Systems," presented at the IEEE WESCON, Los Angeles, CA, August 25-28, 1970.

[3] B. W. Boehm, *Software Engineering Economics*. Englewood Cliffs, NJ: Prentice Hall, 1981.

[4] R. G. Cooper, "Stage-Gate Systems: A New Tool for Managing New Products," *Business Horizons,* vol. 33, no. 3, pp. 44-54, 1990, doi: 10.1016/0007-6813(90)90040-I.

[5] B. W. Boehm, "Guidelines for Verifying and Validating Software Requirements and Design Specifications," in *Euro IFIP 79*, Amsterdam, Netherlands, 1979: P.A. Samet, pp. 711-719.

[6] U. Lindemann and R. Reichwald, *Integriertes Änderungsmanagement*. Berlin Heidelberg, Germany: Springer-Verlag (in German), 1998.

[7] R. Kleedörfer, *Prozeß- und Änderungsmanagement der Integrierten Produktentwicklung* (Konstruktionstechnik München, no. 29). Munich, Germany: Technical University of Munich (in German), 1999.

[8] H. Wildemann, *Änderungsmanagement*, 28th ed. Munich, Germany: TCW (in German), 2020.

[9] M. V. Tatikonda and S. R. Rosenthal, "Technology novelty, project complexity, and product development project execution success: a deeper look at task uncertainty in product innovation," *IEEE Transactions on Engineering Management,* vol. 47, no. 1, pp. 74-87, 2000, doi: 10.1109/17.820727.

[10] A. Newcomb. "Samsung Finally Explains the Galaxy Note 7 Exploding Battery Mess." NBC News. https://www.nbcnews.com/tech/tech-news/samsung-finally-explains-galaxy-note-7-exploding-battery-mess-n710581 (accessed June 30, 2020).

[11] M. J. Loveridge *et al.*, "Looking Deeper into the Galaxy (Note 7)," *Batteries,* vol. 4, no. 1, 2018, doi: 10.3390/batteries4010003.

[12] N. F. Johnson, *Two's Company, Three is Complexity*. Oxford, Great Britain: Oneworld Publications, 2007.

[13] B. Edmonds, "Syntactic Measures of Complexity," Doctoral Thesis, Department of Philosophy, University of Manchester, Manchester, United Kingdom, 1999.

[14] D. Segal. "It's Complicated: Making Sense of Complexity." https://www.nytimes.com/2010/05/02/weekinreview/02segal.html (accessed July 17, 2020).

[15] R. Badii and A. Politi, *Complexity: Hierarchical Structures and Scaling in Physics* (Cambridge Nonlinear Science Series). Cambridge, United Kingdom: Cambridge University Press, 1997.

[16] W. Weaver, "Science and Complexity," *American Scientist,* vol. 36, pp. 536-544, 1948.

[17] K. A. Richardson, P. Cilliers, and M. Lissack, "Complexity Science: A "Gray" Science for the "Stuff in Between"," *EMERGENCE,* vol. 3, no. 2, pp. 6-18, 2001.

[18] S. E. Phelan, "What Is Complexity Science, Really?," *Emergence,* vol. 3, no. 1, pp. 120-136, 2001, doi: 10.1207/S15327000EM0301_08.

[19] P. Cilliers, "What Can We Learn From a Theory of Complexity?," *Emergence,* vol. 2, no. 1, pp. 23-33, 2000, doi: 10.1207/S15327000EM0201_03.

[20] S. H. Strogatz, Sync: How Order Emerges from Chaos in the Universe, Nature, and Daily Life, 1st ed. New York, NY: Hyperion.

[21] S. A. Sheard and A. Mostashari, "Principles of complex systems for systems engineering," *Systems Engineering,* vol. 12, no. 4, pp. 295-311, 2009, doi: 10.1002/sys.20124.

[22] I. Sanders, "WHAT IS COMPLEXITY?," Washington Center for Complexity & Public Policy, Washington, DC, 2003.

[23] M. Cotsaftis, "What Makes a System Complex? - An Approach to Self Organization and Emergence," in *From System Complexity to Emergent Properties*, M. A. Aziz-Alaoui and C. Bertelle Eds. Berlin Heidelberg, Germany: Springer Berlin Heidelberg, 2009, pp. 49-99.

[24] L. J. Vandergriff, "System Engineering in the 21st Century - Implications from Complexity," in *Symposium on Complex Systems Engineering*, RAND Corporation, Santa Monica, CA, 11-12 January 2007.

[25] J. K. DeRosa, A. Grisogono, A. J. Ryan, and D. O. Norman, "A Research Agenda for the Engineering of Complex Systems," in *2008 2nd Annual IEEE Systems Conference*, Montreal, Canada, 7-10 April 2008, pp. 1-8, doi: 10.1109/SYSTEMS.2008.4518982.

[26] B. W. Mar, "BACK TO BASICS AGAIN – A SCIENTIFIC DEFINITION OF SYSTEMS ENGINEERING," *INCOSE International Symposium,* vol. 7, no. 1, pp. 309-316, 1997, doi: 10.1002/j.2334-5837.1997.tb02187.x.

[27] "The Merriam-Webster Dictionary, International Edition," ed: Merriam-Webster Inc, 2016.

[28] J. Hamilton, "The Engineering Profession," Engineering Council, 2000.

[29] R. Frodeman, J. T. Klein, C. Mitcham, and J. B. Holbrook, *The Oxford Handbook of Interdisciplinarity*, first ed. Oxford University Press, 2010.

[30] R. Frodeman, J. T. Klein, and R. C. Dos Santos Pacheco, *The Oxford Handbook of Interdisciplinarity*, second ed. Oxford University Press, 2017.

[31] G. Dandy, D. Walker, T. Daniell, and R. Warner, *Planning and Design of Engineering Systems*, second ed. Taylor & Francis, 2008.

[32] "Systems Engineering - Transforming Needs to Solutions." INCOSE - International Council on Systems Engineering. https://www.incose.org/systems-engineering (accessed December 3, 2019).

[33] A. Kossiakoff, W. N. Sweet, S. J. Seymour, and S. M. Biemer, *Systems Engineering Principles and Practice*, second ed. John Wiley & Sons, 2011.

[34] "Systems Engineering Across Multiple Domains." John Hopkins Whiting School of Engineering. https://ep.jhu.edu/about-us/news-and-media/systems-engineering-across-multiple-domains (accessed December 11, 2019).

[35] "Careers in SE." INCOSE - International Council on Systems Engineering. https://www.incose.org/about-systems-engineering/careers-in-se (accessed December 11, 2019).

[36] C. E. Shannon, "A mathematical theory of communication," *The Bell System Technical Journal,* vol. 27, no. 3, pp. 379-423, 1948, doi: 10.1002/j.1538-7305.1948.tb01338.x.

[37] T. J. McCabe, "A Complexity Measure," *IEEE Transactions on Software Engineering,* vol. SE-2, no. 4, pp. 308-320, 1976, doi: 10.1109/TSE.1976.233837.

[38] S. A. Kauffman, *At Home in the Universe*. Oxford, United Kingdom: Oxford University Press, 1996.

[39] J. Portugali, H. Meyer, E. Stolk, and E. Tan, *Complexity Theories of Cities Have Come of Age*. Berlin Heidelberg, Germany: Springer-Verlag.

[40] P. R. Bryant, "The order of complexity of electrical networks," *Proc. Inst. Elec. Eng.,* vol. 106, pp. 174-188, 1959.

[41] H. A. Simon, "The Architecture of Complexity," *Proceedings of the American Philosophical Society,* vol. 106, no. 6, pp. 467-482, 1962. [Online]. Available: http://www.jstor.org/stable/985254.

[42] E. J. Weyuker, "Evaluating software complexity measures," *IEEE Transactions on Software Engineering,* vol. 14, no. 9, pp. 1357-1365, 1988, doi: 10.1109/32.6178.

[43] S. Lloyd and H. Pagels, "Complexity as thermodynamic depth," *Annals of Physics,* vol. 188, no. 1, pp. 186-213, 1988, doi: 10.1016/0003-4916(88)90094-2.

[44] S. R. Chidamber and C. F. Kemerer, "A metrics suite for object oriented design," *IEEE Transactions on Software Engineering,* vol. 20, no. 6, pp. 476-493, 1994, doi: 10.1109/32.295895.

[45] M. Gell-Mann and S. Lloyd, "Information measures, effective complexity, and total information," *Complexity,* vol. 2, no. 1, pp. 44-52, 1996, doi: 10.1002/(SICI)1099-0526(199609/10)2:1<44::AID-CPLX10>3.0.CO;2-X.

[46] J. H. Holland, *Hidden Order* (Helix Books). Reading, MA: Addison-Wesley, 1996.

[47] V. R. Basili, L. C. Briand, and W. L. Melo, "A validation of object-oriented design metrics as quality indicators," *IEEE Transactions on Software Engineering,* vol. 22, no. 10, pp. 751-761, 1996, doi: 10.1109/32.544352.

[48] C. Collberg, C. Thomborson, and D. Low, "A Taxonomy of Obfuscating Transformations," 1997.

[49] H. A. Bashir and V. Thomson, "Estimating Design Complexity," *Journal of Engineering Design,* vol. 10, no. 3, pp. 247-257, 1999, doi: 10.1080/095448299261317.

[50] C. Adami, C. Ofria, and T. C. Collier, "Evolution of biological complexity," *Proceedings of the National Academy of Sciences,* vol. 97, no. 9, pp. 4463-4468, 2000, doi: 10.1073/pnas.97.9.4463.

[51] C. Eun Sook, K. Min Sun, and K. Soo Dong, "Component metrics to measure component quality," in *Proceedings Eighth Asia-Pacific Software Engineering Conference*, 4-7 December 2001, pp. 419-426, doi: 10.1109/APSEC.2001.991509.

[52] D. W. McShea, "The hierarchical structure of organisms: a scale and documentation of a trend in the maximum," *Paleobiology,* vol. 27, no. 2, pp. 405-423, 2001, doi: 10.1666/0094-8373(2001)027<0405:Thsooa>2.0.Co;2.

[53] P. Romero, Z. Obradovic, X. Li, E. C. Garner, C. J. Brown, and A. K. Dunker, "Sequence complexity of disordered protein," *Proteins: Structure, Function, and Bioinformatics,* vol. 42, no. 1, pp. 38-48, 2001, doi: 10.1002/1097-0134(20010101)42:1<38::AID-PROT50>3.0.CO;2-3.

[54] S. H. Strogatz, "Exploring complex networks," *Nature,* vol. 410, no. 6825, pp. 268-276, 2001, doi: 10.1038/35065725.

[55] J. M. Carlson and J. Doyle, "Complexity and robustness," *Proceedings of the National Academy of Sciences,* vol. 99, no. suppl 1, pp. 2538-2545, 2002, doi: 10.1073/pnas.012582499.

[56] R. Subramanyam and M. S. Krishnan, "Empirical analysis of CK metrics for object-oriented design complexity: implications for software defects," *IEEE Transactions on Software Engineering,* vol. 29, no. 4, pp. 297-310, 2003, doi: 10.1109/TSE.2003.1191795.

[57] H. A. Bashir and V. Thomson, "Estimating design effort for GE hydro projects," *Computers & Industrial Engineering,* vol. 46, no. 2, pp. 195-204, 2004, doi: 10.1016/j.cie.2003.12.005.

[58] D. Bonchev and D. H. Rouvray, *Complexity in Chemistry, Biology, and Ecology*. Boston, MA: Springer Science+Business Media, 2005.

[59] R. M. Hazen, P. L. Griffin, J. M. Carothers, and J. W. Szostak, "Functional information and the emergence of biocomplexity," *Proceedings of the National Academy of Sciences,* vol. 104, no. suppl 1, pp. 8574-8581, 2007, doi: 10.1073/pnas.0701744104.

[60] A. E. Hassan, "Predicting faults using the complexity of code changes," in *2009 IEEE 31st International Conference on Software Engineering*, 16-24 May 2009 2009, pp. 78-88, doi: 10.1109/ICSE.2009.5070510.

[61] C. C. Bozarth, D. P. Warsing, B. B. Flynn, and E. J. Flynn, "The impact of supply chain complexity on manufacturing plant performance," *Journal of Operations Management,* vol. 27, no. 1, pp. 78-93, 2009, doi: 10.1016/j.jom.2008.07.003.

[62] J. P. Crutchfield and K. Wiesner, "Simplicity and Complexity," *Physics World,* vol. February 2010, pp. 36-38, 2010.

[63] F. Isik, "An entropy-based approach for measuring complexity in supply chains," *International Journal of Production Research,* vol. 48, no. 12, pp. 3681-3696, 2010, doi: 10.1080/00207540902810593.

[64] J. D. Summers and J. J. Shah, "Mechanical Engineering Design Complexity Metrics: Size, Coupling, and Solvability," *Journal of Mechanical Design,* vol. 132, no. 2, 2010, doi: 10.1115/1.4000759.

[65] C. P. Panos, K. C. Chatzisavvas, C. C. Moustakidis, N. Nikolaidis, S. E. Massen, and K. D. Sen, "Atomic Statistical Complexity," in *Statistical Complexity: Applications in Electronic Structure*, K. D. Sen Ed. Dordrecht: Springer Netherlands, 2011, pp. 49-64.

[66] W. ElMaraghy, H. ElMaraghy, T. Tomiyama, and L. Monostori, "Complexity in engineering design and manufacturing," *CIRP Annals,* vol. 61, no. 2, pp. 793-814, 2012, doi: 10.1016/j.cirp.2012.05.001.

[67] N. Fenton and J. Bieman, Software Metrics: A Rigorous and Practical Approach, Third Edition. Boca Raton, FL: CRC Press, 2014.

[68] J. Dresner and K. H. Borchers, "Maintenance, Maintainability, and System Requirements Engineering," 1964, SAE Technical Paper 640591.

[69] D. Callele, K. Wnuk, and B. Penzenstadler, "New Frontiers for Requirements Engineering," in *2017 IEEE 25th International Requirements Engineering Conference (RE)*, 4-8 September 2017, pp. 184-193, doi: 10.1109/RE.2017.23.

[70] J. W. Kolligs and L. D. Thomas, "The Origins of Requirements," *IEEE Systems Journal,* pp. 1-11, 2020, doi: 10.1109/JSYST.2020.2999557.

[71] *Systems Engineering Management*, MIL-STD-499, Department of Defense, 1969.

[72] N. R. Mead, "A history of the international requirements engineering conference (RE)RE@21," in *2013 21st IEEE International Requirements Engineering Conference (RE)*, 15-19 July 2013, pp. 21-221, doi: 10.1109/RE.2013.6636721.

[73] M. W. Alford, "A Requirements Engineering Methodology for Real-Time Processing Requirements," *IEEE Transactions on Software Engineering,* vol. SE-3, no. 1, pp. 60-69, 1977, doi: 10.1109/TSE.1977.233838.

[74] M. W. Alford, "Software Requirements Engineering Methodology (SREM) at the age of two," in The IEEE Computer Society's Second International Computer Software and Applications Conference, 1978. COMPSAC '78., 13-16 November 1978, pp. 332-339, doi: 10.1109/CMPSAC.1978.810410.

[75] M. W. Alford, "SREM at the Age of Eight; The Distributed Computing Design System," *Computer,* vol. 18, no. 4, pp. 36-46, 1985, doi: 10.1109/MC.1985.1662863.

[76] IEEE Standard Glossary of Software Engineering Terminology, ANSI/ IEEE Std 729-1983, 1983.

[77] B. W. Boehm, "Verifying and Validating Software Requirements and Design Specifications," *IEEE Software,* vol. 1, no. 1, pp. 75-88, 1984, doi: 10.1109/MS.1984.233702.

[78] P. Loucopoulos and J. Mylopoulos, "Requirements Engineering editorial," *Requirements Engineering,* vol. 8, no. 1, 2003, doi: 10.1007/s00766-003-0172-2.

[79] IEEE Std 830 - IEEE Recommended Practice for Software Requirements Specifications, IEEE, New York, NY, 1998.

[80] IEEE Std 1233 - IEEE Guide for Developing System Requirements Specifications, IEEE, New York, NY, 1998.

[81] ISO/IEC/IEEE International Standard 29148 - Systems and Software Engineering - Life Cycle Processes - Requirements Engineering, ISO/IEC/IEEE, 2011.

[82] W. Hsu and I. M. Y. Woon, "Current research in the conceptual design of mechanical products," *Computer-Aided Design,* vol. 30, no. 5, pp. 377-389, 1998, doi: 10.1016/S0010-4485(97)00101-2.

[83] M. J. Darlington and S. J. Culley, "Current research in the engineering design requirement," Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, vol. 216, no. 3, pp. 375-388, 2002, doi: 10.1243/0954405021520049.

[84] M. Weber and J. Weisbrod, "Requirements engineering in automotive development: experiences and challenges," *IEEE Software,* vol. 20, no. 1, pp. 16-24, 2003, doi: 10.1109/MS.2003.1159025.

[85] C. Hales and S. Gooch, *Managing Engineering Design*. London, United Kingdom: Springer-Verlag, 2004.

[86] K. Elghariani and N. Kama, "Review on Agile requirements engineering challenges," in *2016 3rd International Conference on Computer and Information Sciences (ICCOINS)*, Kuala Lumpur, Malaysia, 15-17 August 2016, pp. 507-512, doi: 10.1109/ICCOINS.2016.7783267.

[87] N. Ramadan and S. Megahed, "Requirements Engineering in Scrum Framework," *International Journal of Computer Applications,* vol. 149, pp. 24-29, 2016, doi: 10.5120/ijca2016911530.

[88] X. Franch *et al.*, "Data-Driven Requirements Engineering in Agile Projects: The Q-Rapids Approach," in *2017 IEEE 25th International Requirements Engineering Conference Workshops (REW)*, Lisbon, Portugal, 4-8 September 2017, pp. 411-414.

[89] F. Gomes De Oliveira Neto, J. Horkoff, E. Knauss, R. Kasauli, and G. Liebel, "Challenges of Aligning Requirements Engineering and System Testing in Large-Scale Agile: A Multiple Case Study," in *2017 IEEE 25th International Requirements Engineering Conference Workshops (REW)*, 4-8 September 2017, doi: 10.1109/REW.2017.33.

[90] R. Kasauli, G. Liebel, E. Knauss, S. Gopakumar, and B. Kanagwa, "Requirements Engineering Challenges in Large-Scale Agile System Development," in *2017 IEEE 25th International Requirements Engineering Conference (RE)*, 4-8 September 2017, pp. 352-361, doi: 10.1109/RE.2017.60.

[91] E.-M. Schön, J. Thomaschewski, and M. J. Escalona, "Agile Requirements Engineering: A systematic literature review," *Computer Standards & Interfaces,* vol. 49, pp. 79-91, 2017, doi: 10.1016/j.csi.2016.08.011.

[92] E.-M. Schön, D. Winter, M. J. Escalona, and J. Thomaschewski, "Key Challenges in Agile Requirements Engineering," Cologne, Germany, 22-26 May 2017: Springer International Publishing, in Agile Processes in Software Engineering and Extreme Programming, pp. 37-51, doi: 10.1007/978-3-319-57633-6_3.

[93] L. Zamudio, J. A. Aguilar, C. Tripp, and S. Misra, "A Requirements Engineering Techniques Review in Agile Software Development Methods," Trieste, Italy, 3-6 July 2017: Springer International Publishing, in Computational Science and Its Applications – ICCSA 2017, pp. 683-698, doi: 10.1007/978-3-319-62404-4_50.

[94] K. Curcio, T. Navarro, A. Malucelli, and S. Reinehr, "Requirements engineering: A systematic mapping study in agile software development," *Journal of Systems and Software,* vol. 139, pp. 32-50, 2018, doi: 10.1016/j.jss.2018.01.036.

[95] F. Dalpiaz and S. Brinkkemper, "Agile Requirements Engineering with User Stories," in *2018 IEEE 26th International Requirements Engineering Conference (RE)*, Banff, Alberta, Canada, 20-24 August 2018, pp. 506-507.

[96] H. Villamizar, M. Kalinowski, M. Viana, and D. M. Fernández, "A Systematic Mapping Study on Security in Agile Requirements Engineering," in *2018 44th Euromicro Conference on Software Engineering and Advanced Applications (SEAA)*, 29-31 August 2018, pp. 454-461, doi: 10.1109/SEAA.2018.00080.

[97] S. Wagner, D. Méndez Fernández, M. Kalinowski, and M. Felderer, "Agile Requirements Engineering in Practice: Status Quo and Critical Problems," *CLEI Electronic Journal,* vol. 21, no. 1, Paper 6, 2018, doi: 10.19153/cleiej.21.1.6.

[98] E.-M. Schön, J. Sedeño, M. Mejías, J. Thomaschewski, and M. J. Escalona, "A Metamodel for Agile Requirements Engineering," *Journal of Computer and Communications,* vol. 7, no. 2, pp. 1-22, 2019, doi: 10.4236/jcc.2019.72001.

[99] Z. S. H. Abad, M. Noaeen, and G. Ruhe, "Requirements Engineering Visualization: A Systematic Literature Review," in *2016 IEEE 24th International Requirements Engineering Conference (RE)*, 12-16 September 2016, pp. 6-15, doi: 10.1109/RE.2016.61.

[100] F. Dalpiaz, A. Ferrari, X. Franch, and C. Palomares, "Natural Language Processing for Requirements Engineering: The Best Is Yet to Come," *IEEE Software,* vol. 35, no. 5, pp. 115-119, 2018, doi: 10.1109/MS.2018.3571242.

[101] M. Ghasemi, "What Requirements Engineering can Learn from Process Mining," in 2018 1st International Workshop on Learning from other Disciplines for Requirements Engineering (D4RE), 21-21 August 2018, doi: 10.1109/D4RE.2018.00008.

[102] S. AlZu'bi, B. Hawashin, M. ElBes, and M. Al-Ayyoub, "A Novel Recommender System Based on Apriori Algorithm for Requirements Engineering," in *2018 Fifth International Conference on Social Networks Analysis, Management and Security (SNAMS)*, 15-18 October 2018, pp. 323-327, doi: 10.1109/SNAMS.2018.8554909.

[103] J. A. Khan, L. Liu, L. Wen, and R. Ali, "Crowd Intelligence in Requirements Engineering: Current Status and Future Directions," in *25th International Working Conference, REFSQ 2019*, Essen, Germany, 18-21 March 2019: Springer International Publishing, in Requirements Engineering: Foundation for Software Quality, pp. 245-261, doi: 10.1007/978-3-030-15538-4_18.

[104] W. Maalej, M. Nayebi, and G. Ruhe, "Data-Driven Requirements Engineering - An Update," in 2019 IEEE/ACM 41st International Conference on Software Engineering: Software Engineering in Practice (ICSE-SEIP), Montreal, QC, Canada, 25-31 May 2019, doi: 10.1109/ICSE-SEIP.2019.00041.

[105] F. Dalpiaz, E. Paja, and P. Giorgini, Security Requirements Engineering: Designing Secure Socio-Technical Systems. Cambridge, MA: MIT Press, 2016.

[106] S. T. Bulusu, R. Laborde, A. Samer Wazan, F. Barrère, and A. Benzekri, "Which Security Requirements Engineering Methodology Should I Choose?: Towards a Requirements Engineering-based Evaluation Approach," in *ARES '17: Proceedings of the 12th International Conference on Availability, Reliability and Security*, Reggio Calabria, Italy, 29 August - 01 September 2017, doi: 10.1145/3098954.3098996.

[107] S. ur Rehman and V. Gruhn, "Security Requirements Engineering (SRE) Framework for Cyber-Physical Systems (CPS): SRE for CPS," in *New Trends in Intelligent Software Methodologies, Tools and Techniques*, H. Fujita, A. Selamat, and S. Omatu Eds. Amsterdam, Netherlands: IOS Press, 2017, pp. 153-163.

[108] S. T. Bulusu, R. Laborde, A. S. Wazan, F. Barrère, and A. Benzekri, "A Requirements Engineering-Based Approach for Evaluating Security Requirements Engineering Methodologies," Las Vegas, NV, 2018: Springer International Publishing, in Information Technology - New Generations, pp. 517-525, doi: 10.1007/978-3-319-77028-4_67.

[109] Y. Mufti, M. Niazi, M. Alshayeb, and S. Mahmood, "A Readiness Model for Security Requirements Engineering," *IEEE Access,* vol. 6, pp. 28611-28631, 2018, doi: 10.1109/ACCESS.2018.2840322.

[110] L. E. G. Martins and T. Gorschek, "Requirements Engineering for Safety-Critical Systems: An Interview Study with Industry Practitioners," *IEEE Transactions on Software Engineering,* vol. 46, no. 4, pp. 346-361, 2020, doi: 10.1109/TSE.2018.2854716.

[111] M. Niazi, A. M. Saeed, M. Alshayeb, S. Mahmood, and S. Zafar, "A maturity model for secure requirements engineering," *Computers & Security,* vol. 95, 2020, doi: 10.1016/j.cose.2020.101852.

[112] S. Wagner *et al.*, "Status Quo in Requirements Engineering: A Theory and a Global Family of Surveys," *ACM Transactions on Software Engineering and Methodology,* vol. 28, no. 2, Article 9, 2019, doi: 10.1145/3306607.

[113] U. Lindemann, M. Maurer, and T. Bran, *Structural Complexity Management* (An Approach for the Field of Product Design). Berlin Heidelberg, Germany: Springer-Verlag, 2009.

[114] D. Weidmann, N. Kattner, C. Hollauer, L. Becerril, N. Chucholowski, and U. Lindemann, "Methods collection to support requirements engineering with focus on structuring and consolidation of requirements," in *2016 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)*, 4-7 December 2016, pp. 1215-1219, doi: 10.1109/IEEM.2016.7798071.

[115] M. A. Jacobs, "Product Complexity: A Definition and Impacts on Operations," *Decision Line,* vol. 38, no. 5, pp. 6-12, 2007.

[116] C. Y. Baldwin and K. B. Clark, Design Rules, Vol. 1: The Power of Modularity. Cumberland, RI: MIT Press, 2000.

[117] A. Griffin, "The Effect of Project and Process Characteristics on Product Development Cycle Time," *Journal of Marketing Research,* vol. 34, no. 1, pp. 24-35, 1997, doi: 10.2307/3152062.

[118] A. Griffin, "Modeling and measuring product development cycle time across industries," *Journal of Engineering and Technology Management,* vol. 14, no. 1, pp. 1-24, 1997, doi: 10.1016/S0923-4748(97)00004-0.

[119] F. P. Brooks, "No Silver Bullet Essence and Accidents of Software Engineering," *Computer,* vol. 20, no. 4, pp. 10-19, 1987, doi: 10.1109/MC.1987.1663532.

[120] S. Gupta and V. Krishnan, "Integrated component and supplier selection for a product family," *Production and Operations Management,* vol. 8, no. 2, pp. 163-182, 1999, doi: 10.1111/j.1937-5956.1999.tb00368.x.

[121] M. A. Jacobs and M. Swink, "Product portfolio architectural complexity and operational performance: Incorporating the roles of learning and fixed assets," *Journal of Operations Management,* vol. 29, no. 7, pp. 677-691, 2011, doi: 10.1016/j.jom.2011.03.002.

[122] J. Göpfert, "Modulare Produktentwicklung," in *Innovationsforschung und Technologiemanagement: Konzepte, Strategien, Fallbeispiele*, N. Franke and C.-F. von Braun Eds. Berlin Heidelberg, Germany: Springer-Verlag, 1998, pp. 139-151.

[123] F. Heylighen, "The Growth of Structural and Functional Complexity during Evolution," in *The Evolution of Complexity*, F. Heylighen, J. Bollen, and A. Riegler Eds. Dordrecht, Netherlands: Kluwer Academic Publishers, 1999, pp. 17-44.

[124] C. Weber, "What is "Complexity"?," in *ICED 05: 15th International Conference on Engineering Design*, Melbourne, Australia, A. Samuel and W. Lewis, Eds., 15-18 August 2005.

[125] D. Baccarini, "The concept of project complexity—a review," *International Journal of Project Management,* vol. 14, no. 4, pp. 201-204, 1996, doi: 10.1016/0263-7863(95)00093-3.

[126] D. Braha, *A Mathematical Theory of Design: Foundations, Algorithms and Applications* (Applied Optimization, no. 17). Dordrecht, Netherlands: Springer Science+Business Media, 1998.

[127] K. Sinha, "Structural Complexity and its Implications for Design of Cyber-Physical Systems," Doctor of Philosophy, Engineering Systems Division, Massachusetts Institute of Technology, 2014.

[128] K. Sinha and E. S. Suh, "Pareto-optimization of complex system architecture for structural complexity and modularity," *Research in Engineering Design,* vol. 29, no. 1, pp. 123-141, 2018, doi: 10.1007/s00163-017-0260-9.

[129] K. Sinha, E. S. Suh, and O. de Weck, "Integrative Complexity: An Alternative Measure for System Modularity," *Journal of Mechanical Design,* vol. 140, no. 5, 2018, doi: 10.1115/1.4039119.

[130] K. Sinha, S.-Y. Han, and E. S. Suh, "Design structure matrix-based modularization approach for complex systems with multiple design constraints," *Systems Engineering,* vol. 23, no. 2, pp. 211-220, 2020, doi: 10.1002/sys.21518.

[131] A. C. Benabdellah, I. Bouhaddou, and A. Benghabrit, "Holonic multi-agent system for modeling complexity structures of Product Development Process," in *2019 4th World Conference on Complex Systems (WCCS)*, 22-25 April 2019, pp. 1-6, doi: 10.1109/ICoCS.2019.8930714.

[132] W. Vogel and R. Lasch, "Complexity drivers in product development: A comparison between literature and empirical research," *Logistics Research,* vol. 11, no. 7, pp. 1-42, 2018, doi: 10.23773/2018_7.

[133] D. Vyron, F. Panos, and F. O. K. James, "Modeling Software Development Process Complexity," *International Journal of Information Technology Project Management (IJITPM),* vol. 9, no. 4, pp. 17-40, 2018, doi: 10.4018/IJITPM.2018100102.

[134] A. Sihvonen and K. Pajunen, "Causal complexity of new product development processes: a mechanism-based approach," *Innovation,* vol. 21, no. 2, pp. 253-273, 2019, doi: 10.1080/14479338.2018.1513333.

[135] A. Açıkgöz, A. Günsel, C. Kuzey, and G. Seçgin, "Functional Diversity, Absorptive Capability and Product Success: The Moderating Role of Project Complexity in New Product Development Teams," *Creativity and Innovation Management,* vol. 25, no. 1, pp. 90-109, 2016, doi: 10.1111/caim.12155.

[136] N. Fain, R. Žavbi, and N. Vukašinović, "The influence of product complexity on team performance within NPD," in *Proceedings of the DESIGN 2016 14th International Design Conference*, Dubrovnik, Croatia, D. Marjanovic, M. Storga, N. Pavkovic, N. Bojcetic, and S. Skec, Eds., May 16-19 2016, pp. 2069-2080.

[137] A. S. Cui and F. Wu, "The Impact of Customer Involvement on New Product Development: Contingent and Substitutive Effects," *Journal of Product Innovation Management,* vol. 34, no. 1, pp. 60-80, 2017, doi: 10.1111/jpim.12326.

[138] T. Mauerhoefer, S. Strese, and M. Brettel, "The Impact of Information Technology on New Product Development Performance," *Journal of Product Innovation Management,* vol. 34, no. 6, pp. 719-738, 2017, doi: 10.1111/jpim.12408.

[139] C. S. Katsikeas, C. N. Leonidou, and A. Zeriti, "Eco-friendly product development strategy: antecedents, outcomes, and contingent effects," *Journal of the Academy of Marketing Science,* vol. 44, no. 6, pp. 660-684, 2016, doi: 10.1007/s11747-015-0470-5.

[140] J.-P. Schöggl, R. J. Baumgartner, and D. Hofer, "Improving sustainability performance in early phases of product design: A checklist for sustainable product development tested in the automotive industry," *Journal of Cleaner Production,* vol. 140, Part 3, pp. 1602-1617, 2017, doi: 10.1016/j.jclepro.2016.09.195.

[141] S. Kim and S. K. Moon, "Eco-modular product architecture identification and assessment for product recovery," *Journal of Intelligent Manufacturing,* vol. 30, no. 1, pp. 383-403, 2019, doi: 10.1007/s10845-016-1253-7.