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KEY PERFORMANCE INDICATORS BASED SOFTWARE ECOSYSTEM (SECO) RESEARCH USING PUBLICATIONS SYSTEMATIC MAPPING

Melnuk K.V., Melnuk V.M., Khrystynets N.A. Key performance indicators based software ecosystem research using publications systematic mapping. To create value with a software ecosystem, a platform owner has to ensure that the SECO is well and sustainable. Key Performance Indicators (KPI) are used to assess whether and how well such objectives are met and what the platform owner can do to improve. This paper gives research overview on KPI-based SECO assessment using research publications systematic mapping. The study identified 34 publications for which KPI research and KPI practice were extracted and mapped. It describes the strengths and gaps of the research published later and what KPI are measured, analyzed, and used for decision-making from the researcher's point of view. The maps that capture state-of-knowledge can be used to plan further research. For practitioners, the generated map points to studies that describe how to use KPI for SECO managing.
Keywords: Software ecosystem, digital ecosystem, performance indicator, KPI, success factor, systematic mapping.

Мельник К.В., Мельник В.М., Христинец Н.А. Ключевые индикаторы функционирования входящие в исследование экосистемы программного обеспечения, используя систематическое картографическое отображение. Чтобы создать значение с экосистемой программного обеспечения, владельцу платформы придется гарантировать, что SECO хороший и работоспособный. Ключевые показатели деятельности (KPI) использованы, чтобы оценить, насколько хорошо выбраны цели и что владелец платформы может сделать для улучшения. Эта статья дает исследовательский краткий обзор оценке SECO на базе KPI, пользуясь систематической картографией исследовательских публикаций. Изучение идентифицировало 34 публикации, для которых были извлечены и изображены исследование и практика KPI. Это описывает силы и пробелы исследования, изданного позже и что KPI, есть взвешенный, проанализировавший, и использованный для принятия решения с точки зрения исследователя. Изображения содержат взятый уровень знаний и может быть использовано, чтобы планировать дальнейшее исследование. Для специалистов-практиков производимая карта указывает на изучение, которое описывает, как пользоваться KPI для SECO.
Ключевые слова: экосистема программного обеспечения, цифровая экосистема, показатель деятельности, KPI, фактор успеха, систематическая картография.

Мельник К.В., Мельник В.М., Христинець Н.А. Ключові індикатори функціонування що входять в основу дослідження екосистеми програмного забезпечення, користуючись систематичною картографією публікацій. Щоб створити значення з екосистемою програмного забезпечення, власникові платформи доведеться гарантувати, що SECO хороша і роботоздатна. Ключові показники діяльності (KPI) використані, для оцінки чи добре підібрані є цілі і що власник платформи може зробити для поліпшення. Ця стаття дає короткий дослідницький огляд на основі оцінки KPI SECO, користуючись систематичною картографією дослідницьких публікацій. Вивчення ідентифікувало 34 публікації, для яких були витягнуті і зображені дослідження і практика KPI. Це описує сили і недоліки дослідження, виданого пізніше і що KPI зрівноважений, аналізуючий, і використаний для прийняття рішення з точки зору дослідника. Зображення містять виявлений рівень знань і можуть бути використані для планування подальших досліджень. Для практикуючих фахівців карта відображення вказує на вивчення, яке описує, як користуватися KPI для SECO.
Ключові слова: екосистема програмного забезпечення, цифрова екосистема, індикатор діяльності KPI, фактор успіху, систематична картографія.

Introduction

A software ecosystem (SECO) is about actors set interaction functioning as a unit and interacting with a shared market for software and services together with the relationship among them [1]. Here is reviewed any ecosystem that basing on or enabled by software, including pure software, software-intensive systems, mobile applications, cloud, telecommunications, and digital software ecosystems. The inclusion of telecommunications, for example, can only be realized with appropriate ICT infrastructure. Companies adopt SECO strategy to enlarge their organizational boundaries, to share their platforms and resources with third parties and to define new business models [2, 3]. A SECO is often supported by a technological platform or market that enables the SECO actors in exchanging information, resources, and artifacts. Ownership of such a platform gives strategic advantages over the other SECO actors. It allows ever-increasing customer demands satisfaction with limited own resources. It also KPIs for Software Ecosystems: A Systematic Mapping Study 195 allows improving one's own knowledge about the marketplace that is necessary for innovation, evolution of a product or service offering, and revenue opportunities identification [4, 5].

SECO platform ownership also brings responsibilities which include the definition of SECO performance objectives and SECO management to achieve these objectives. It also is expected to be healthy [6] and sustainable [7]. It is healthy when it is productive for surrounding actors, robust, and niche-creating [8]. It is sustainable when it maintains its structure and functioning in a resilient manner

[6]. Health and sustainability are closely linked performance objectives that are often found in complex systems [9, 10]. Managing involves definition of how actors, software, and business models play together to achieve the SECO objectives in business, technical, and social dimensional perspectives [11, 12]. The platform owner uses performance indicators for benchmarking and monitoring the resulting ecosystem behavior. Key performance indicators (KPI) are those among many possible indicators that are important, easily measurable quantitatively or with a qualitative phenomenon approximation [13]. The KPI serve as early warnings about potentially missed SECO objectives [14] and used to detect patterns that are useful for predicting health and sustainability [15]. Any deviation from success baselines are recorded and acted upon to ensure about main ecosystem's objectives are met. The presented study gives a literature overview of KPI for software ecosystems. A systematic mapping methodology was surveyed to identify and classify publications based on the reported research and on KPI use. The used for classifying research dimensions were the studied type of ecosystem and the result type was delivered by the research. The dimensions used for classifying KPI use were investigated KPI types, the SECO objectives were used these KPI for. The knowledge gap for collecting evidences about KPI studies motivated systematically evaluate distribution of studies and provide guidance for future improvement. For practitioners, the generated map describes how to use KPI in the SECO management. It enables the platform owner in indicators understanding that are important to assess given SECO objectives. For researchers, the generated map describes research state and helps finding research gaps for definition understanding and SECO KPI use.

Research Methodology

The goal of this study is to provide research overview performed to investigate the use of KPI for managing software ecosystems. The systematic mapping approach [16] allows to map the frequencies of publications over categories to see the current state of research. It also exposes patterns or trends of what research kind is done or respectively has been ignored so far. The research results mapping in addition to the research type reveals researchers' current understanding of KPI-related practice.

To provide an overview on publications relevant to KPI use for SECO, two sets of research questions are defined in Table 1. With the first set of questions we mapped foci and gaps for SECO KPI research. With the second set we mapped the practice state that was reported by the research.

Research Questions.

SECO KPI Research Rationale. RQ1: What kinds of ecosystems were studied? The answer to this question shows the SECO KPI research intensity across domains and types of ecosystem application. Due to a focus on just a few types of application domains and ecosystems, skewedness indicates gaps where additional research is need. RQ2: What types of research were performed? The answer to this question shows the maturity of SECO KPI research. The more disproportioned conceptual solutions and empirical validation research are, the more there is a need for research to compensate.

Ecosystem KPI Practice Rationale. RQ3: What objectives were KPI used for? The answer to this question shows the SECO KPI purposes. It allows understanding when a SECO is considered to be successful and not. The answer to RQ4 correlation allows understanding how the SECO objectives satisfaction is measured. RQ4: What ecosystem entities and attributes did the KPI correspond to? The answer to this question gives a relevant KPI overview that are used to assess SECO objectives achievement. The KPI show how SECO objectives are operationalized and quantified. Skewedness, focusing on just one or a few KPI, may indicate the degree of universality that KPI have for SECO management.

Systematic Mapping Approach

To answer RQ1, RQ3, we followed the systematic mapping guidelines proposed in [16]. We: conducted database search with a search string matching to our research scope; performed screening to select the relevant papers; built a classification scheme based on keywording the paper titles, abstracts, and keywords; and used this classification scheme to map the papers. To answer RQ2, we modified the mapping process by using the pre-existing classification schemes already used in [16, 17]. For RQ4, we built the classification scheme by extracting keywords from the main body of the papers and aligning the emerging scheme with the relevant software industry standard. The research steps are explained below.

I Database Search. The study defined the following search strategy.

Search String. To get an unbiased overview of KPI use in SECO, the search string was created with keywords that capture population only. The first aspect used to define the population was the ecosystems that can be found in a software context: software, digital, mobile, service, cloud, telecommunication and

ICT ecosystems. We also included papers that focused on software supply by adding software supply to the search string. The second aspect used to define the population was the KPI application or use. It was used the term indicators, metrics, measurements, success factors, key characteristics and quality attributes as synonyms for KPI. To avoid bias about RQ3, we did neither constrain for what purpose information was gathered and used. To build a broad overview of the research area and avoid bias, no keywords were defined in relation to intervention (e.g. monitoring), outcomes (e.g. improvements to SECO), or study designs (e.g. case studies). The search string was built by concatenating the two population aspects with the *AND* operator. The search string was formulated as follows:

Software OR *(software-intensive)* OR *digital* OR *mobile* OR *service* OR *cloud* OR *communic** OR *telecom** OR *ICT PRE/0 (ecosystem** OR *"supply network*")* AND *(measure** OR *kpi** OR *metric** OR *analytic** OR *indicator** OR *"success factor*"* OR *"quality attribute*"* OR *"key characteristic*"*.

Search Strategy. The papers were identified using the important research databases in software engineering and computer science including Scopus, Inspec, and Compendex, which support IEEEXplore and ACM Digital Library as well. The search string was applied to title, author's keywords and papers abstract. The search did not restrict the publication date.

Validation. It was validated the identified papers set by checking it against the papers used in the SECO literature reviews performed by [2, 5]. Each paper used by these studies that was relevant for our study had been found by following the above-outlined database search.

II Screening of Papers. The inputs for this step were the set of papers identified with step (I). The first and second authors screened these papers independently. It was screened these papers to exclude studies not related to the KPI use for any ecosystem-related purpose and to ensure broad-enough coverage of the population. Next a complete set of inclusion and exclusion criteria is described.

Inclusion. It was included peer-reviewed journal, conference, or workshop papers that were accessible with full text. The included papers describe the use of KPI in an ecosystem context or the effects of such KPI on ecosystem properties. Due to the importance of networking infrastructure and digital information exchange for a well-functioning software ecosystem there was included telecommunication and information technology papers in addition to pure SECO papers.

Exclusion. There was excluded papers that focused on the KPI use for managing an ecosystem member only. For example, papers about the indicators use for managing a single company that participates in the ecosystem or a product or company process were excluded because of their too narrow focus. It was also excluded papers that focused on other ecosystems rather than a software ecosystem. For example, papers focused on biology, environmental, climate, and chemical aspects were excluded. When the software ecosystem definition did not fulfill in the papers, they were excluded. As an example, the paper that considered Bugzilla and email system as software ecosystems was excluded, since such systems do not address the shared market concept of SECO definition. Papers that studying qualitative indicators using qualitative approaches such as a structured interview were too excluded. Also, it was excluded papers that focused on ecosystem design in place of ecosystem management. For example, papers about the design of interoperability protocols, products, services offered to ecosystem were excluded. To avoid inclusion of papers that only speculated about KPI use or effects, it was excluded papers that did not report any empirically-grounded proof-of-concept.

III Building the Classification Scheme. To answer the research questions RQ1, RQ3 and RQ4 it was applied keywording [16] as a technique to build the classification scheme in a bottom-up manner. Extracted Keywords were grouped under higher categories to make categories more informative and to reduce number of similar categories. The ecosystem classification scheme was built by extracting the types and application domains of the studied ecosystems. It was built the classification scheme for KPI practice by extracting KPI assessment objectives, entities and attributes used for measuring KPI. The keywords were extracted from the papers' titles, keywords, and abstracts. When the abstract quality was too poor, to identify the keywords was used the paper main body. Similarly, as most of the papers did not included sufficient information about entities and attributes measured with KPI inside the abstract, the main papers body was used for keyword identification. The keywords obtained from extraction were then combined and clustered to build the categories used for mapping the papers. The measurement attributes clustering was aligned with the categories described in ISO/IEC FDIS 25010 as far as applicable. To answer RQ2, it was used a pre-defined classification scheme [17] that was used by earlier systematic mapping studies [16]. It classifies research types into validation research, evaluation research, solution proposals, philosophical papers, opinion papers, and experience papers.

IV Systematic Mapping of the Papers. When the classification scheme was ready, the selected papers were sorted into the classification scheme. Then classifications calculated the frequencies of publications for each category. To answer RQ1 and RQ2 was reported the frequencies of the selected papers for the categories in the dimensions of ecosystems types and application domains, respectively in the dimensions of research type and research contributes type. We used x-y scatterplots with bubbles in category intersections to visualize the kinds of studied ecosystems. The size of a bubble is depicted proportional to the number of papers that are in the pair of categories corresponding to the bubble coordinates. The visualized frequencies make possible to see which categories have been emphasized in past research and which of them received little or no attention. To answer RQ3, first was described the categories identified when building the classification scheme and how these categories were expressed in the selected papers. This description resulted in a dictionary for interpreting the scatterplots used for describing how SECO KPI are used for these objectives. Again, x-y scatterplots were used for showing the frequency of categories pairs. These pairs allowed to describe the attributes measured for each type of ecosystem entity, the measurements used in relation to the SECO objectives, and how KPI are obtained for various kinds of entities found in SECO.

Threats to Validity

The threats to validity are analyzed for construct taxonomies, reliability, internal and external validity. *Construct validity* reflects whether the papers included in the study reflect the SECO KPI phenomenon that was intended to be researched. The search string was constructed in an inclusive manner so that it captured the wide variety of software-related ecosystems and the many different names given to key performance indicators. The common databases, used for software and management-related literature research, were used to find papers. Only after this inclusive process, manual screening was performed to exclude papers not related to the research objectives. The list of included papers was then validated against two systematic studies on software ecosystem [2, 5] and found that the review covers all relevant papers.

Reliability validity refers to the study repeatability for other researchers. The study applied a defined search string, used deterministic databases, and followed a step-by-step procedure that can be easily replicated. The stated inclusion and exclusion criteria were systematically applied. Reliability of the classification was achieved by seeking consensus among multiple researchers.

Internal validity treats refers to problems in the data analysis. These threats are small, since only descriptive statistics were used.

External validity concerns the ability to generalize from this study. Generalization is not an aim of a systematic mapping study as only one research state is analyzed and the relevant research body completely covered. In particular, the study results about the SECO KPI use reflects the practices studied in SECO KPI research and not SECO KPI practice performed in general.

Ecosystem KPI Research Results

The database search resulted 262 papers in total, including 46 duplicates. After screening and exclusion 34 papers remained and were included in the study. Selected papers were published from 2004 onwards. It will be given an overview of the research described in the selected papers and app. A lists the selected papers.

Kinds of Ecosystems. To answer RQ1, Figure 1 gives an overview over the ecosystems that our study found for KPI research. The number embedded in a bubble indicates how many papers were devoted to a given combination of ecosystem type and application domain (multiple classifications possible). Empty cells indicate that no corresponding study was found. The number on the category label indicates the total number of papers in that category. Most of the papers used the term software ecosystem to characterize the studied ecosystems. Special kinds of ecosystems were cloud, service, mobile apps, and open source software ecosystems. Less frequent were digital ecosystems with 44% of the papers. They refer to the use of IT to enable collaboration and knowledge exchange [16]. The papers addressed a variety of application domains. Most common were telecommunications, business management and software development. None of the remaining application domains was addressed by more than one or two papers. Thus, research is rather scattered, and the specifics of the various application domains understood only little.

Types of Research. To answer RQ2, Fig. 1 presents a map of the research kinds performed on KPI in software-related ecosystems. Papers with multiple research types and contributions were classified for each research type combination and contribution they presented.

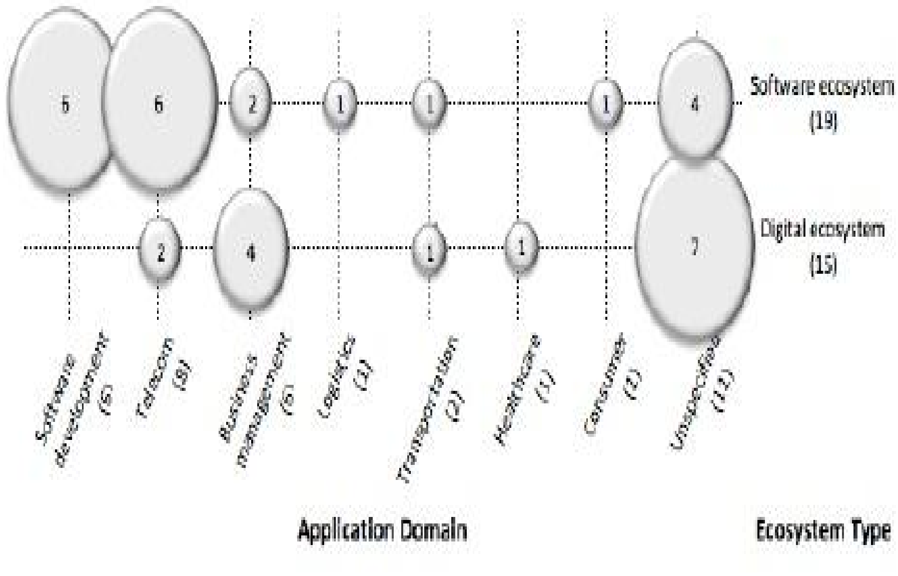


Fig. 1. Map of research on SECO KPI and type of contributions

Experience report papers describe experiences in working with SECO KPI and unsolved problems.
Opinion papers discuss opinions of the papers' authors.
Conceptual proposal papers sketch new conceptual perspectives related to SECO KPI. This category renamed *philosophical papers* category (described in III) to fit the SECO KPI study.
Solution proposal papers propose new methods or improve existing techniques using a small example or a good argumentation.
Validation papers investigate novel solutions that had not been implemented in practice (e.g. experiment, lab working).
Evaluation papers report on empirical or formal studies performed to implement a solution or evaluate the implementation.
Metric papers describe KPI for SECO.
Model papers describe relationships between KPI.
Method papers describe approaches for working with SECO KPI.
Tool papers describe support for work with SECO KPI.

Most research were found in the validation and evaluation categories. Research contributed with metrics, models, or methods. For example, R17 proposes a model that explains how health can be measured with relevant indicators (conceptual proposal, model) and validates that model with a questionnaire (validation, model). R14 proposes a method for assessing services based on Service indicators Quality (solution, method). R19 evaluates factors that affect successful selling in e-markets (metric, evaluation). No paper was with the experience report or an opinion paper and no paper were contributed with any tool.

Researched KPI Practice Results

In this study the papers included described use of KPI by a platform owner for achieving objectives with the ecosystem that was enabled by the ecosystem platform. It is given an overview of these objectives and used KPIs.

Ecosystem Objectives Supported by KPI. KPI were used to enable or achieve a variety of objectives. Platform owners aimed, at improving business, interconnectedness between actors and quality of ecosystem, product, or services performed within the ecosystem, at ecosystem growing and at enabling ecosystem sustainability (answer RQ3):

Business improvement. Research has been made on how to improve business at the ecosystem level. The studied business improvements concerned the perspectives of ecosystem activity and commercial success. Ecosystem activity related to the activity level of participating actors, encouragement to participate in the ecosystem, and the transaction volume. Commercial success related to sales success, innovativeness and competitiveness of the participating actors, and the network cost that enables the ecosystem. The activity and commercial perspectives were mixed in the papers, thus could not be separated in the literature analysis.

Interconnectedness improvement. Research has been performed on how to improve interaction in an ecosystem, for example to reduce cost, improve predictability of services that are provided in the ecosystem, and manage trust. Interaction improvement has been studied between individual actors and between whole networks contained in the ecosystem. The research differed in lifecycle stage terms of an interaction and covered supplier availability, discovery, ranking and selection, the resulting connectivity, interaction evaluation, and the interaction actors' impact that participated in it. Interaction improvement was considered essential for generating business activity and ecosystem sustainability.

Growth and stability. Research has been made on how to manage ecosystem growth and stability. They were seen as two factors that have to be managed jointly. During growth flexibility and controllability has to be maintained. During stability, a continuous co-revolution must take place. Growth and stability again are not ends in themselves, but thus contribute to ecosystem sustainability and survival.

Quality improvement. Research has been performed on how to manage quality of ecosystems. In particular, performance, usability, security, data reliability, extendibility, transparence, trustworthiness, and quality-in-use were investigated here. Quality management was sometimes presented as an ends in itself, for example by allowing comparison among multiple ecosystems, enabling diagnosis, improving decision-making, and achieving services long-term usage. At the same time, however, quality management was considered to be a means to encourage adoption and growth, improve business performance, and achieve sustainability.

Enable sustainability. Research has been made on how to sustain an ecosystem. Two angles were taken: self-organization and resource consumption. Self-organization was approached through continuous ecosystem rejuvenation. Resource consumption was studied in relation of electrical energy. Throughout all papers found in this category, sustainability was considered to be desirable ends for software ecosystems.

KPI Measured Entities. Included papers describe measurements applied to the ecosystem as to the parts the ecosystem consists of: actor, artifact, service, relationship, transaction and network.

Actors were measured and characterized as follows. They were human or artificial. Examples of human or legal actors were sellers and developers that provide products to buyers or organizations and companies groups. Examples of artificial actors were nodes in a telecommunication network. An actor engages in transactions in ecosystem and builds relationships to other actors or artifacts. The transactions engages the seller in generate profit and revenue for the cost the seller is keen to take. Effective actors have knowledge about other actors or network, good interestingness and reputation for other actors. Actors are also considered to be sources and sinks of data and have differing ranges for data transmission. Performance of individuals and groups in terms of fulfilled tasks and decisions as well as firms and organizations performance in measured terms of profits.

Artifacts, such as software, codes, plugins, books, music, or data were measured and characterized as follows. Artifacts had a location in the ecosystem. They evolve, may have reputation and popularity, and exposed their consumers to vulnerability.

Services were measured and characterized as consuming energy and other resources. Services have quality attributes: service quality, security, compliance and reputation. Metadata and service level agreements are used to specify the services. The services are not fixed but evolve: services emerge, change, and get extinct. A special service was provided by the platform that laid the fundament for the ecosystem. It was characterized in attributes terms like stability, documentation, portability, and openness.

Relationships were measured and characterized as follows. Actors enter relationships with other actors, artifacts, or services. A relationship connects two or more such entities. Relationship examples were business connections and telecommunication communication links. A relationship may be transparent and express a trust value of the connected entities. A relationship is the basis for transactions, thus is used for advertising and building alliances. The transaction, however, is constrained by relationship cost and quality.

Transactions were measured and characterized as follows. Examples of transactions are services sales to customers, server requests, and code files commits made by developers. They are initiated with an offer that is measured in attributes terms like price and quantity. Transactions also have a price and quantity. Other attributes include time to negotiate the transaction, time to complete, energy consumption, transmission rate, and buyer satisfaction.

Networks were considered as sets of entities and relationships that were part of a whole ecosystem. Examples were local or application-specific networks. Networks were vulnerable to security threats such as data availability, integrity, authentication and authorization. They differed in the node density, collaboration degree, provisioning cost, and hit rate for artifacts.

Ecosystem. Full ecosystems have quality attributes like size, performance, security and energy consumption that can also characterize networks contained in an ecosystem. In addition, ecosystems exhibited lifelines, diversity, stability, transparency, healthiness and sustainability. This section and next one collaboratively provide an answer for RQ4. The map in the left part of Figure 3 shows the entities that were studied in relation to the ecosystem objectives. Most research studied the overall ecosystem measurement to enable quality or business improvement. For example, R17 describes how performance of the ecosystem affected user satisfaction, and R13 shows how analytics applied to ecosystem can be used to improve business. Considerable research was also devoted to ecosystem interconnectedness improving, where products attributes and services played an important role including for platform measurements to grow the ecosystem and improve its quality. For example, R6 described how a service similarity measurement was used to improve ecosystem connectivity. R2 described how growth, diversity, and entropy measurements of a SOA platform were used to increase growth. R4 described how communication quality measurements were used to improve the telecommunication ecosystem quality. The map also shows areas where no research was published. For example, no one research studied the network measurements role for objectives other than sustainability and quality improvement.

KPI Measurement Attributes

To make the state and evolution of the ecosystem and its elements visible, a broad variety of attributes were measured. The following attributes categories emerged when clustering the attributes described in the included papers. Fig. 4 shows how quality attributes classes were merged toward new categories. The *size* category includes attributes to measure size and growth. *Diversity* includes attributes to measure heterogeneity and openness for such heterogeneity. *Financial* includes attributes to measure economic aspects such as investment, cost, and price. *Satisfaction* includes attributes to measure it and the related concepts of suitability, interestingness, learnability, usability, accessibility, acceptability, trust, and reputation. *Performance* includes attributes to measure it, including resource utilization, efficiency, accuracy and effectiveness. *Freedom from risk* includes attributes to measure the ability to avoid or mitigate risks and includes the related security concerns, reliability, maturity, availability, and other related guarantees. *Compatibility* includes attributes to measure the degree to which an entity can perform well in a given context, interoperate or exchange information with other entities and be ported from one context to another. *Maintainability* includes attributes to measure flexibility, respectively the ability to be changed. The right part of Fig. 3 gives an overview of the attributes referred to KPI. Most research studied satisfaction measurements typically to improve business or interconnectedness. Such research example is R13 that describes the seller reputation use to improve business. To support quality improvement all measurement attributes related to quality were included in at least one research paper, except for maintainability and size. Similarly, size measurements did not play any role other than for growth and stability. The left part of Fig. 5 shows how the ecosystem elements were measured. Satisfaction was a common attribute that was measured for any entity except for rules. This shows that a same attribute can be measured or analyzed for different ecosystem entities. It is also revealed that similar measurement attributes might be collaborating to measure different ecosystem elements. As an example correlation, commitment, clarity and importance (CCCI) measurable attributes were used to measure trust as well as reliability.

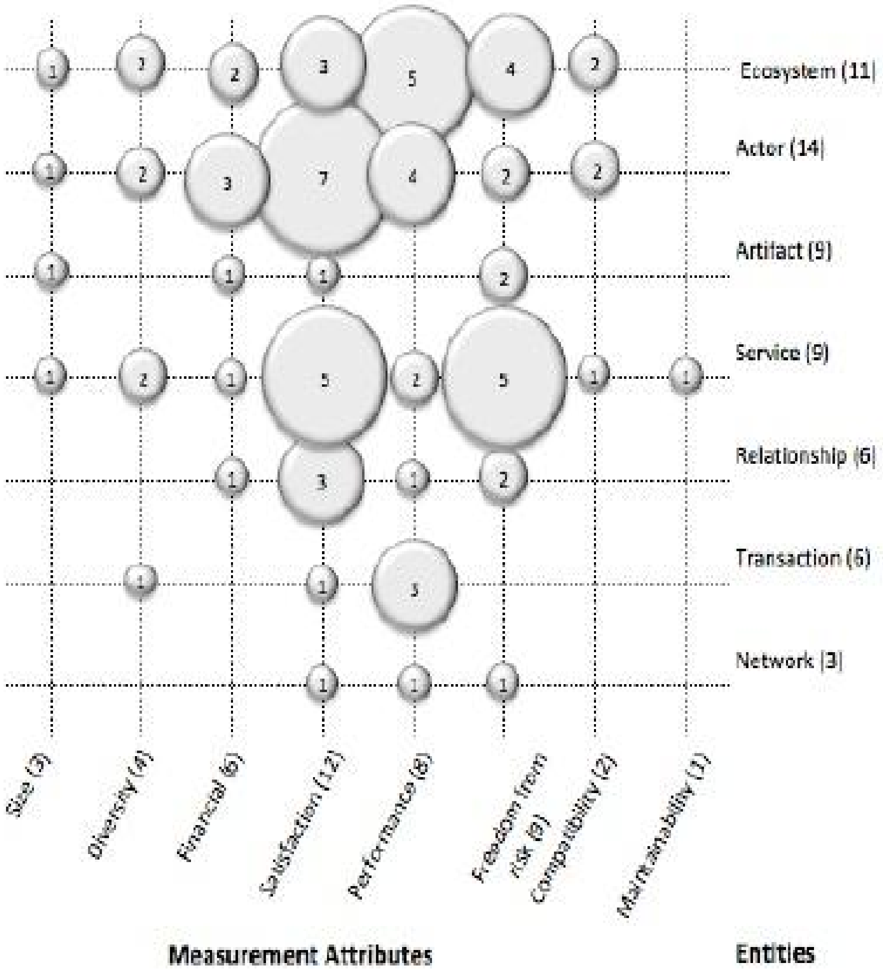
Diversity	*Satisfaction*	*Performance*	*Financial*	*Size*	*Freedom from risk*	*Compatibility*	*Maintainability*
Heterogeneity Openness	Learnability Usability Accessibility Acceptability Trust Reputation	Satisfaction Suitability Interestingness Performance Resource utilization Efficiency Accuracy Effectiveness	Investment Cost Price	Size Growth	Risk mitigation Security Reliability Maturity Availability Guarantees	Interoperability Exchangeability	Flexibility Changeability

Fig. 2. Measurement attributes merging classifications

The overall ecosystem was the most comprehensively measured or analyzed entity with a special focus on satisfaction, freedom from risks and performance. Some examples of such satisfaction measurements are provided by R13 that measured ecosystem usage and acceptability. The platform tailed with the second-largest variety of measurements. R2, for example, measured entropy and diversity to characterize platform complexity. Only narrow sets of measurement attributes were applied to the business partner, interactions, and business.

Discussion

The study provides a KPI relevant papers classification in understanding researches, relationship with the practice and research outcomes assessment. This classification contributes to taxonomy, which can help for closer examination of the ecosystem or platform owner objectives, making them more recognizable in designing KPI. New KPI can be extracted for an ecosystem using this taxonomy and existing KPIs can be extended or restructured applying the generic taxonomy structure. The literature map indicates that KPI for software-based ecosystems is a thin area with work at all maturity levels. Journal, conference and workshop papers exist. However, the number of publications is not sufficient and many application domains for ecosystems addressed with just one or two papers. Although KPI formulation might be domain dependent and similarity of objectives is not the only factor to select a KPI, however, due to insufficient study it is difficult to state whether domain characteristics, for example healthcare regulation, affects the ecosystem KPI that targets that domain. The included research on ecosystem KPI mostly addresses ecosystem measurements or satisfaction measurements, performance and freedom from risks. Measurements other than satisfaction that are applied on elements contained in the ecosystem are comparatively little researched. A KPI broader understanding would increase a platform owner's flexibility in measuring, analyzing, and using KPI for decision-support. The understanding of a greater KPI variety would also contribute to increased status transparency, evolution, and other ecosystem aspects.



Conclusion

Presented study gives literature overview for KPI use with software-based ecosystems. A systematic mapping methodology was followed and applied to 34 included studies published from 2004 onwards. To respond to RQ1 and RQ2, research was broad but thin. Two major kinds of ecosystems were researched: software ecosystems and digital ecosystems. Many application domains were addressed, but most of them with one or two papers only. The published research was mature with journal, conference, and workshop papers that covered metrics, models, and methods. In response to RQ3 and RQ4, KPI research was skewed. Most research studied ecosystem KPI for improving the interconnectedness between individual actors and subsystems of the ecosystem. Overall, most KPI were about satisfaction, performance and freedom from risks measures. The mapping study results indicate that more research is needed to better KPI understanding for software-based ecosystems. In particular, a deeper understanding of how the application domain affects the ecosystem's KPI is needed. Also, an important research opportunity is the identification, analysis, and evaluation of KPI. Such research could make the work with KPI more flexible, because a greater KPI variety would be known and available for the practitioner to use.

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