KPIs for Software Ecosystems: A Systematic Mapping Study

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Abstract. To create value with a software ecosystem (SECO), a platform owner has to ensure that the SECO is healthy 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 an overview of existing research on KPI-based SECO assessment using a systematic mapping of research publications. The study identified 34 relevant publications for which KPI research and KPI practice were extracted and mapped. It describes the strengths and gaps of the research published so far, and describes what KPI are measured, analyzed, and used for decision-making from the researcher's point of view. For the researcher, the maps thus capture state-of-knowledge and can be used to plan further research. For practitioners, the generated map points to studies that describe how to use KPI for managing of a SECO.

Keywords: software ecosystem, digital ecosystem, performance indicator, KPI, success factor, systematic mapping.

1 Introduction

A software ecosystem (SECO) is about "the interaction of a set of actors functioning as a unit and interacting with a shared market for software and services, together with the relationship among them" [1]. We include here any ecosystem that is based 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, is important as many modern software services can only be realized with appropriate ICT infrastructure. Companies adopt a SECO strategy to expand their organizational boundaries, to share their platforms and resources with third parties, and to define new business models [2, 3].

A SECO is frequently 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 satisfying ever-increasing customer demands with limited own resources. It also

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allows improving one's own knowledge about the marketplace. Such knowledge is necessary for innovation, evolution of a product or service offering, and identification of revenue opportunities [4, 5].

SECO platform ownership also brings responsibilities. These include the definition of SECO performance objectives and management of the SECO to achieve these objectives. A SECO 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 [9] that are often found in complex systems [10].

Managing a SECO involves definition of how actors, software, and business models play together to achieve the SECO objectives [11] in business, technical, and social dimensional perspectives [12]. The platform owner uses performance indicators for benchmarking and monitoring the resulting ecosystem behavior. Key performance indicators (KPI) are those among the many possible indicators that are important, easily measurable quantitatively or with an approximation of qualitative phenomena [13]. The KPI serve as early warnings about potentially missed SECO objectives [14] and to detect patterns that are useful for predicting health and sustainability of the SECO [15]. Any deviation from success baselines are recorded and acted upon to ensure that the main ecosystem's objectives are met.

The here presented study gives an overview of literature on KPI for software ecosystems. A systematic mapping methodology was followed to identify and classify publications based on the reported research and based on KPI use. The dimensions used for classifying research were the type of ecosystem that was studied and the type of result that was delivered by the research. The dimensions used for classifying KPI use were the researched KPI types, the SECO objectives these KPI were used for.

The knowledge gap for collecting evidences about KPI studies motivated to systematically evaluate distribution of studies and provide guidance for future improvement. For practitioners, the generated map describes how to use KPI in the management of a SECO. It enables the platform owner in understanding the indicators that are important to assess for given SECO objectives. For researchers, the generated map describes state of research and helps finding research gaps for understanding the definition and use of SECO KPI.

The remainder of the paper is structured as follows. Section 2 presents the research objectives and defines research questions, search strategy, study selection, and study quality assessment. Sections 3 and 4 present the results by giving an overview of SECO KPI research, respectively SECO KPI practice. Section 5 discusses the results. Section 6 summarizes and concludes.

2 Research Methodology

The goal of this study is to provide an overview of the research 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 kind of research is done, respectively has been ignored so far. Mapping the research results, in addition to the type of research, reveals researchers' current understanding of KPI-related practice.

2.1 Research Questions

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 of research about SECO KPI. With the second set we mapped the state of practice that was reported by the research.

Table 1. Research Questions

SECO KPI Research	**Rationale**
RQ1: What kinds of ecosystems were studied?	The answer to this question shows the intensity of SECO KPI research across application domains and types of ecosystems. Skewedness, e.g. due to a focus on just a few types of application domains and ecosystems, indicates gaps where additional research is needed.
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 that compensates.
Ecosystem KPI Practice	**Rationale**
RQ3: What objectives were KPI used for?	The answer to this question shows the purposes of SECO KPI. It allows understanding when a SECO is considered to be successful and when not. Correlation with the answer to RQ4 allows understanding how the satisfaction of these SECO objectives is measured.
RQ4: What ecosystem entities and attributes did the KPI correspond to?	The answer to this question gives an overview of relevant KPI that are used to assess achievement of SECO objectives. The KPI show how SECO objectives are operationalized and quantified. Skewedness, a focus on just one or a few KPI, may indicate the degree of universality the KPI have for SECO management.

2.2 Systematic Mapping Approach

To answer RQ1, RQ3, we followed the systematic mapping guidelines proposed by Petersen [16]. We (i) conducted database search with a search string that matched our research scope, (ii) performed screening to select the relevant papers, (iii) built a classification scheme based on keywording the papers' titles, abstracts, and keywords, and (iv) 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 application or use of KPI. We used the terms 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 a 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 (measur* 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 abstract of these papers. The search did not restrict the date of the publication.

Validation. We validated the set of identified papers 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 We screened these papers to exclude studies that do not relate to the use of KPI for any ecosystem-related purpose and to ensure broad-enough coverage of the population. We describe here a complete set of inclusion and exclusion criteria.

Inclusion. We 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 properties of the ecosystem. Due to the importance of networking infrastructure and digital information exchange for a well-functioning software ecosystem we included telecommunication and information technology papers in addition to pure SECO papers.

Exclusion. We excluded papers that focused on the use of KPI for managing a member of the ecosystem only. For example, papers about the use of indicators for managing a single company that participates in the ecosystem, or a product or process of that company, were excluded because of their too narrow focus. We excluded papers that focused on other ecosystems rather than a software ecosystem. For example papers focus on biology, environmental, climate, and chemical aspects were excluded. When the definition of software ecosystem 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 a SECO definition. Papers that study qualitative indicators using qualitative approaches such as a structured interview were excluded. Also, we excluded papers that focused on ecosystem design in place of ecosystem management. For example, papers about the design of interoperability protocols or of products or services offered to an ecosystem were excluded. The papers that do not Finally, to avoid inclusion of papers that only speculated about KPI use or effects, we 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 we employed 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. We built the ecosystem classification scheme by extracting the types and application domains of the studied ecosystems. We built the classification scheme for KPI practice by extracting KPI assessment objectives, entities and attributes used for measuring the KPI.

The keywords were extracted from the papers' titles, keywords, and abstracts. When the quality of an abstract was too poor, we used the main body of the paper to identify the keywords. Similarly, as most of the papers did not included sufficient information about entities and attributes measured with KPI inside the abstract, we used the main body of the papers for keyword identification. The keywords obtained from extraction were then combined and clustered to build the categories used for mapping the papers. The clustering of measurement attributes was aligned with the categories described in ISO/IEC FDIS 25010 as far as applicable.

To answer RQ2, we 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 in place, the selected papers were sorted into the classification scheme. The classifications were then calculated the frequencies of publications for each category.

To answer RQ1 and RQ2 we 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 ecosystems that were studied. The size of a bubble is depicted proportional to the number of papers that are in the pair of categories that correspond to the bubble coordinates. The visualized frequencies make it possible to see which categories have been emphasized in past research and which categories received little or no attention.

To answer RQ3, we first 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 in relation to these objectives. We again used x-y scatterplots for showing the frequency of pairs of categories. These pairs allowed us 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 a SECO.

2.3 Threats to Validity

This section analyzes the threats to validity for the taxonomies of construct, 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 repeatability of the study 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 analysis of the data. 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 state of research is analyzed and the relevant body of research completely covered. In particular, the study results about the use of SECO KPI, reflects the practices studied in SECO KPI research and not SECO KPI practice performed in general.

3 Results: Ecosystem KPI Research

The database search resulted in a total of 262 papers, including 46 duplicates. After screening and exclusion, 34 papers remained and were included in the study. These selected papers were published from 2004 onwards. This section gives an overview of the research described in the selected papers. Appendix A lists the selected papers.

3.1 Kinds of Ecosystems

To answer RQ1, Figure 1 gives an overview over the ecosystems that our study found KPI research for. 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 [18].

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 only little understood.

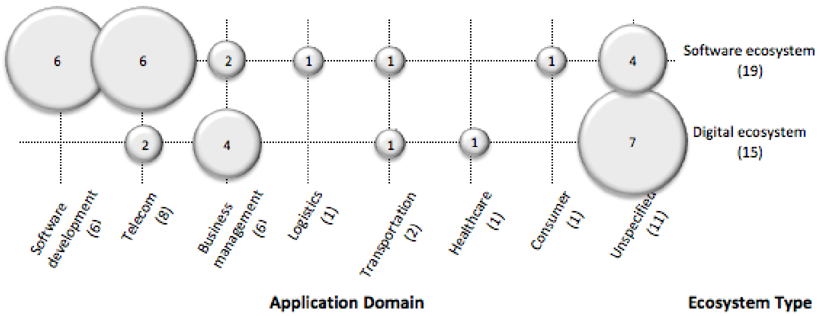

Fig. 1. Kinds of ecosystems that were studied with KPI research. The label "software ecosystem" refers to those that are not considered a digital ecosystem (see main text).

3.2 Types of Research

To answer RQ2, Figure 2 presents a map of the kind of research performed on KPI in software-related ecosystems. Papers with multiple research types and contributions were classified for each combination of research type and contribution they presented.

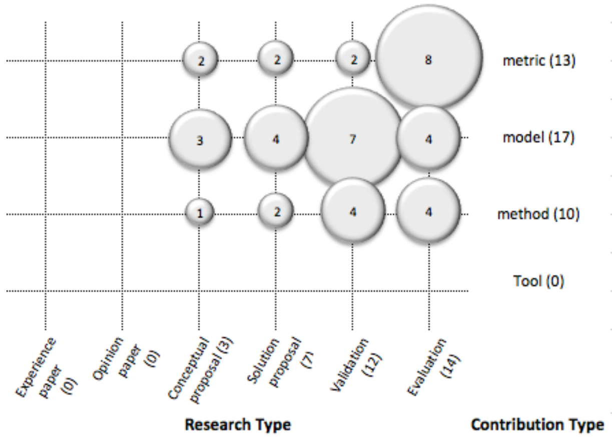

Fig. 2. Map of research on SECO KPI and type of contributions

Experience report papers describe experiences in working with SECO KPI and usually describe 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 of section 2.2) to fit the SECO KPI study. *Solution proposal* papers propose new techniques 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. Finally, *tool* papers describe support for work with SECO KPI.

Most research was found in the categories of validation and evaluation. 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 Quality of Service indicators (solution, method). R19 evaluates factors that affect successful selling in e-markets (metric, evaluation). No paper was an experience report or an opinion paper. No paper contributed with any tool.

4 Results: Researched KPI Practice

The papers included in this study describe the use of KPI by a platform owner for achieving objectives with the ecosystem that was enabled by the ecosystem platform. This section gives an overview of these objectives and the KPI that were used.

4.1 Ecosystem Objectives Supported by KPI

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

Business improvement. Research has been performed on how to improve business at the ecosystem level. The studied business improvements concerned the perspectives of ecosystem activity and of commercial success. Ecosystem activity related to the level of activity 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 cost of the network that enables the ecosystem. The activity and commercial perspectives were mixed in the papers, thus could not be separated in the analysis of the literature.

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 was studied between individual actors and between whole networks contained in the ecosystem. The research differed in terms of lifecycle stage of an interaction and covered supplier availability, discovery, ranking and selection, the resulting connectivity, interaction evaluation, and the impact of the interaction on the actors that participated in it. Interaction improvement was not always an end in itself, but was considered essential for generating business activity and sustainability of the ecosystem.

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

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. 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 long-term usage of services. 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 performed on how to sustain an ecosystem. Two angles were taken: self-organization and resource consumption. Self-organization was approached through continuous rejuvenation of the ecosystem. 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.

4.2 KPI: Measured Entities

The included papers describe measurements applied to the ecosystem as a whole as to the parts the ecosystem consists of: actor, artifact, service, relationship, transaction and network.

Actors. 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 groups of organizations and firms. Examples of artificial actors were nodes in a telecommunication network. An actor engages in transactions in an ecosystem and builds relationships to other actors or artifacts. The transactions the seller engages in generate profit and revenue for the cost the seller is willing to take. Effective actors have knowledge about other actors or the network and has 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 performance of firms and organizations in terms of profits are measured.

Artifacts. 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. Services were measured and characterized as follows. Services consume energy and other resources. Services have quality attributes such as quality of service, 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 terms of attributes like stability, documentation, portability, and openness.

Relationship. Relationships were measured and characterized as follows. Actors enter relationships with other actors, artifacts, or services. A relationship connects two or more such entities. Examples of relationships 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 cost and quality of the relationship.

Transactions. Transactions were measured and characterized as follows. Examples of transactions are sales of services to customers, server requests, and commits of code files made by developers. They are initiated with an offer that is measured in terms of attributes 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.

Network. 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 characterized as follows. Networks were vulnerable to security threats such as data availability, integrity, authentication, and authorization. Networks differed in the node density, degree of collaboration, provisioning cost, and hit rate for artifacts.

Ecosystem. Full ecosystems were characterized as follows. They 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 section collaboratively provide 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 measurement of the overall ecosystem 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 the ecosystem can be used to improve business. Considerable research was also devoted to improving the interconnectedness of the ecosystem, where attributes of the products and services played an important role and also to the role of platform measurements to grow the ecosystem and improve quality. For example, R6 described how to use 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 quality of a telecommunication ecosystem.

The map also shows areas where no research was published. For example no research studied the role of network measurements for objectives other than sustainability and quality improvement.

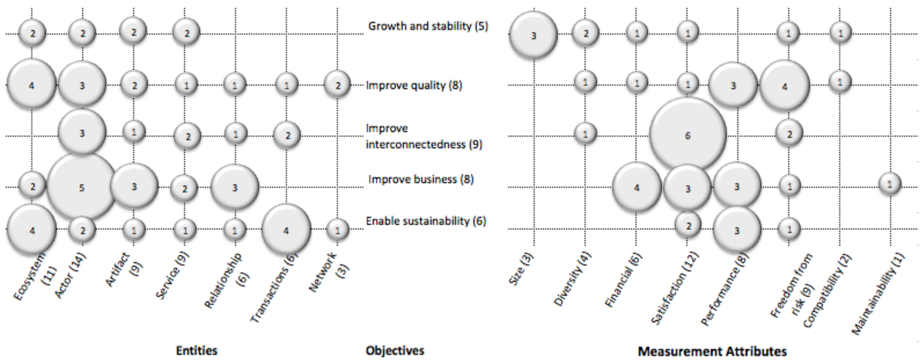

Fig. 3. Map of measured entities and measurement attributes in relation to ecosystem objectives

4.3 KPI: Measurement Attributes

To make the state and evolution of the ecosystem and of its elements visible, a broad variety of attributes were measured.

The following attributes categories emerged when clustering the attributes described in the included papers. Figure 4 shows how classes of quality attributes 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 satisfaction and the related concepts of suitability, interestingness, learnability, usability, accessibility, acceptability, trust, and reputation. *Performance* includes attributes to measure performance, 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 concerns of security, 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 one. *Maintainability* includes attributes to measure flexibility, respectively the ability to be changed.

The right part of Figure 3 gives an overview of the attributes referred to by KPI. Most research studied measurements of satisfaction, typically to improve business or interconnectedness. An example of such research is R13 that describes the use of seller reputation to improve business. To support quality improvement, all measurement attributes that relate 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 Figure 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. Also it is revealed that similar measurement attributes might be collaborating to measure different ecosystem elements. As an example CCCI (correlation, commitment, clarity and importance) measurable attributes were used to measure trust as well as reliability.

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

Fig. 4. Merging classifications of measurement attributes

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 usage and acceptability of an ecosystem. The platform followed 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.

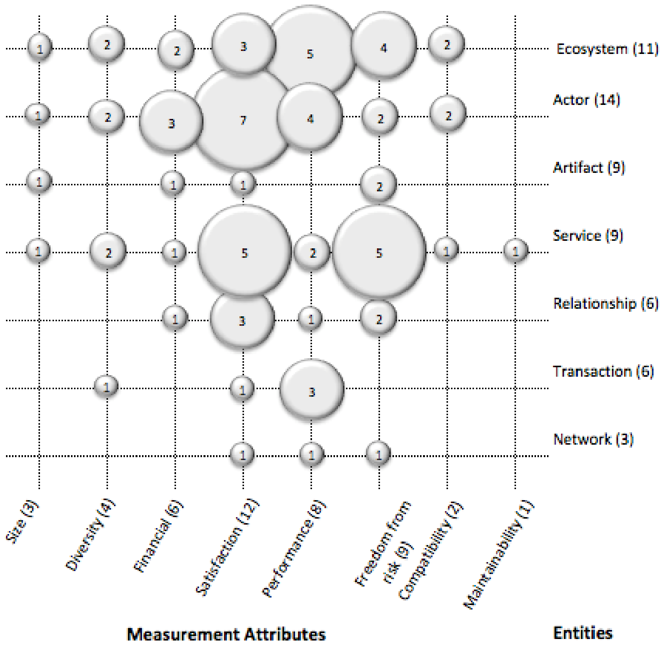

Fig. 5. Map of measurement attributes in relation to the measured entities

5 Discussion

The study provides a classification of KPI relevant papers in understanding researches, relationship with the practice, and assessment of research outcomes. 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 structure of the taxonomy.

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 formulation of KPI 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 characteristics of a domain, for example regulation of healthcare, affects the KPI of the ecosystem that targets that domain.

The included research on ecosystem KPI mostly addresses ecosystem measurements or measurements of satisfaction, performance and freedom from risks. Measurements other than satisfaction that are applied on elements contained in the ecosystem are comparatively little researched. A broader understanding of KPI would increase a platform owner's flexibility in measuring, analyzing, and using KPI for decision-support. The understanding of a greater variety of KPI would also contribute to increased transparency of status, evolution, and other aspects of the ecosystem.

6 Conclusion

The here presented study gives an overview of literature on the use of KPI for 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 results of the mapping study indicate that more research is needed to better understanding of KPI for software-based ecosystems. In particular, a deeper understanding of how the application domain affects an 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 variety of KPI would be known and available for the practitioner to use.

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7 Appendix I: The Selected Studies

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R1	Sabry, N., Krause, P.: A digital ecosystem view on cloud computing. 6th IEEE International Conference on Digital Ecosystems Technologies (DEST). Piscataway, NJ, USA (2012)
R2	Fiegler, A., Dumke, R.R.: Growth-and Entropy-Based SOA Measurement: Vision and Approach in a Large Scale Environment. Software Measurement,Joint Conference of the 21st Int'l Workshop on and 6th Int'l Conference on Software Process and Product Measurement (IWSM-MENSURA). Los Alamitos, CA, USA (2011)
R3	Pranata, I., Skinner, G., Athauda, R.: TIDE: Measuring and evaluating trustworthiness and credibility of enterprises in digital ecosystem. International Conference on Management of Emergent Digital EcoSystems. San-Francisco, USA (2011)
R4	Yang, Y., Xu, Y., Li, X., Chen, C.: A loss inference algorithm for wireless sensor networks to improve data reliability of digital ecosystems. Industrial Electronics, IEEE Transactions on 58, 2126-2137 (2011)
R5	Savola, R.M., Sihvonen, M.: Metrics driven security management framework for e-health digital ecosystem focusing on chronic diseases. International Conference on Management of Emergent Digital EcoSystems. Addis Ababa, Ethiopia (2012)
R6	Dong, H., Hussain, F.K., Chang, E.: A service concept recommendation system for enhancing the dependability of semantic service matchmakers in the service ecosystem environment. Journal of Network and Computer Applications 34, 619-631 (2011)
R7	Barolli, L., Yang, T., Mino, G., Durresi, A., Xhafa, F.: A simulation system for WSNs as a Digital Eco-System approach considering goodput metric. 4th IEEE International Conference on Digital Ecosystems and Technologies (DEST). Dubai, United Arab Emirates (2010)
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R9	Fabregues, A., Madrenas-Ciurana, J., Sierra, C., Debenham, J.: Supplier performance in a digital ecosystem. 3rd IEEE International Conference on Digital Ecosystems and Technologies, DEST'09. Istanbul, Turkey (2009)
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R12	Dong, H., Hussain, F.K., Chang, E.: Semantic service retrieval and QoS measurement in the digital ecosystem environment. International Conference on Complex, Intelligent and Software Intensive Systems (CISIS). Krakow, Poland (2010)

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R14	Chen, W., Chang, E.: A method for service quality assessment in a service ecosystem. International Conference on Digital Ecosystems and Technologies Inaugural IEEE. Piscataway, NJ, USA (2007)
R15	Koendjbiharie, S., Koppius, O., Vervest, P., van Heck, E.: Network transparency and the performance of dynamic business networks. 4th IEEE International Conference on Digital Ecosystems and Technologies (DEST). Dubai, United Arab Emirates (2010)
R16	Jansen, S.: How quality attributes of software platform architectures influence software ecosystems. International Workshop on Ecosystem Architectures. Saint Petersburg, Russian Federation (2013)
R17	Salem, A.M.B.H., Ghadhab, B.B.: Performance Measurement practices in Software Ecosystem. International Journal of Productivity and Performance Management. 62, 514 - 533 (2013)
R18	Goeminne, M., Mens, T.: A framework for analysing and visualising open source software ecosystems. Joint ERCIM Workshop on Software Evolution (EVOL) and International Workshop on Principles of Software Evolution (IWPSE). Antwerp, Belgium (2010)
R19	Pereira, A., Duarte, D., Meira Jr, W., Góes, P.: Assessing success factors of selling practices in electronic marketplaces. International Conference on Management of Emergent Digital EcoSystems. Lyon, France (2009)
R20	Dong, H., Hussain, F.K., Chang, E.: A QoS-based service retrieval methodology for digital ecosystems. International Journal of Web and Grid Services 5, 261-283 (2009)
R21	Fachrunnisa, O., Hussain, F.K.: A methodology for maintaining trust in industrial digital ecosystems. IEEE Transactions on Industrial Electronics 60, 1042-1058 (2013)
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R30	Straub, D., Rai, A., Klein, R.: Measuring firm performance at the network level: A nomology of the business impact of digital supply networks. Journal of Management Information Systems 21, 83-114 (2004)
R31	Vasilescu, B., Serebrenik, A., Goeminne, M., Mens, T.: On the variation and specialisation of workload-A case study of the Gnome ecosystem community. Empirical Software Engineering - Article in Press (2013)
R32	Luna, J., Ghani, H., Vateva, T., Suri, N.: Quantitative Assessment of Cloud Security Level Agreements: A Case Study. 7th International Conference on Security and Cryptography. SECRYPT. INSTICC Press, Setubal, Portugal (2012)
R33	van Angeren, J., Blijleven, V., Jansen, S.: Relationship intimacy in software ecosystems: a survey of the dutch software industry. International Conference on Management of Emergent Digital EcoSystems. ACM, San Francisco, CA, USA (2011)
R34	Liu, Y., Fan, Y., Huang, K.: Service Ecosystem Evolution and Controlling: A Research Framework for the Effects of Dynamic Services. International Conference on Service Sciences (ICSS). IEEE, Shenzhen, China (2013)