Application Landscape Metrics:
Overview, Classification, and Practical Usage

Jan Stefan Addicks, Philipp Gringel

Software Engineering for Business Information Systems
OFFIS - Institute for Information Technology
Escherweg 2
26121 Oldenburg, Germany
{jan.stefan.addicks, philipp.gringel}@offis.de

Abstract: Due to mergers and acquisitions as well as uncoordinated projects, application landscapes of today's organizations contain redundant applications (two or more applications that have similar functionality). To consolidate the application landscape, comparisons of applications have to be performed. Application landscape metrics are seen as an appropriate instrument for such comparisons. This contribution describes a method as well as a template to classify landscape metrics. In presenting a tool prototype, we provide a first glance of how to practically employ application landscape metrics.

1   Introduction

The everyday business of today's organizations is supported by numerous business applications that form an application landscape (denoted as *landscape*). Landscapes continuously grow in complexity, due to continuous adaptations in order to fulfill business requirements. This leads to an increasing number of heterogeneous interwoven applications [Add09]. Since applications support business processes, they are also affected by alignment to changing customer markets or new market situations.

In order to improve the quality of landscapes, adequate documentation is essential. Stakeholders (like chief information officers (CIOs)) being in charge of the landscapes rely on documentation to manage current and plan future states. Scientific approaches often focus on modeling and documenting the landscape and the interconnections with hardware infrastructure and business elements (cf. [Fra02], [Lan05] and [WS06]). These results are complemented by commercial tools to support these issues. An overview of major tools can be found in [MBLS08], [Jam08] and [Pey07]. Since landscapes are part of enterprise architectures (EA), these tools typically address EA as a whole.

Nevertheless, in disciplines like IT consolidation (cf. [Kel07]), a well documented landscape alone is still insufficient to adequately support stakeholders. When two or more applications with similar functionality have to be compared to each other in order to determine the one that best suits the landscape, additional instruments are necessary. Land-

scape metrics as well as assessment and evaluation methods for landscapes seem suitable here. The mentioned techniques generate comparable values for each application under investigation. Based on the results, stakeholders can decide which application is to be removed from the landscape. So far, no established metrics-centered methods exist that allow for flexible as well as multiple usage of application landscape metrics (denoted as *landscape metrics* in the following), but several approaches address similar issues (cf. [Dur06], [Gam07], [GSL07], [Lan08], or [LS08]).

These approaches differ from classical software metrics (cf. [FP98] or [KKC00]), since the latter are used to evaluate the quality of single software systems within the software engineering phase and explicitly do not regard the environment in an organizational context. However, this aspect is important for the evaluation of an application within a landscape, since the properties of one application can influence characteristics of another (cf. [Add09]). For instance, the response time of an application can depend on the response time of another. Besides application-to-application dependencies, the quality classification of applications can further depend on other aspects, like strategic decisions or regulations from authorities (i.e. SOX (Sarbanes-Oxley Act) compliance or Basel II compliance [Kel07]).

To this point, there are neither fixed definitions of metrics for these concerns in general nor common overviews of landscape metrics. In order to present an overview of the current situation regarding landscape metrics we have performed a literature analysis. The objective was to identify landscape metrics as well as key figures that can be used to evaluate and benchmark applications regarding their landscape context. The identified metrics and key figures were classified using a method and a classification template which are both presented in this contribution. The resulting overview of existing landscape metrics provides a foundation for practitioners to choose adequate metrics to evaluate their landscapes.

When metrics are established in organizations, resulting key figures could effectively be used for monitoring purposes and benchmarking. Since software map visualizations [Wit07] are commonly used to provide overviews of landscapes, key figures can be depicted in such maps by small icons next to the symbol representing an application to indicate the value of an application's property, e.g. its quality. Tools providing this functionality exist (cf. planning IT from alfabet); however, those are in general based on proprietary models and metrics that often can not be customized easily by the user.

Tools that support various metrics and allow for integrating individual metrics have not come into the market so far. Thus, stakeholders are in general not able to define metrics on their own and use them for evaluation purposes. In order to motivate the practical usage of landscape metrics, we present a software prototype, which allows for flexible usage of metrics and various kinds of representations for the results.

The remainder of this paper is structured as follows: The next section presents a foundation of key figures and metrics and takes a quick glance at the state-of-the-art of landscape metrics. An overview of relevant research work is also given. Section 3 presents the research method, on which the results of this contribution are founded. We describe a method by which landscape metrics from different sources can be captured and compared to each other in a unified manner. The results of our literature research are summarized

in section 4. The usage of landscape metrics with our prototype is shown in section 5 before the last section sums up this contribution and gives an outlook on future research activities.

2   Metrics and Key Figures

We start this section by defining the central concepts of our contribution. According to [Küt09] a *key figure* captures facts quantitatively and in an aggregated manner, which means they are often used to map a large amount of data to few significant values. A key figure is the result of measuring a defined property using a concrete metric. A *metric* is a measuring specification (often a mathematical formula), that belongs to a property (e.g. the availability of an application). The metric defines in which way a resulting key figure has to be determined. Landscape metrics are used to evaluate applications' properties with regard to the dependencies within a landscape and thus are not limit to application-specific properties.

With regard to literature, the field of landscape metrics is rather young. There is only little literature available focusing on such aspects, but the number has continuously increased recently. Landscape metrics are intended to support CIOs by means of providing additional information of the applications' quality. However, there are only few case studies of metrics usage so far (mostly from academia like [LS08]).

This is in accordance with the results of a survey conducted by Lankes in 2007 (cf. [Lan08]). According to the survey, only 37% of the surveyed practitioners indicated that their organization actually uses metrics; however, 52% predicted a possible usage for the future. Only 11% of the surveyed practitioners regarded metrics as not applicable.

By means of presenting an overview of existing landscape metrics, we provide a foundation for practitioners to adapt these for their organization where appropriate. Nevertheless, there are further challenges to face. For instance, Lankes et al. [LS08], state the difficulty to convince CIOs to use metrics, because the difficulty in gathering the required data and correctly interpreting the metrics' results is perceived as an obstacle. The consumption of valuable time and resources for gathering the required data is seen as the main obstacle. Thus, the metrics' usage has to be as efficient and effective as possible, to provide more benefit to the people in charge.

Tool-support for the evaluation is additionally required to assist the process. Although there are tools that provide similar functionality, such as EAM (EA management) tools (cf. [MBLS08] for a survey of major tools), most of them cannot be extended or customized to meet individual requirements with respect to metrics.

We could not locate any comprehensive overview of metrics to evaluate landscapes. However single key figures and metrics suitable for evaluation of landscapes are presented and used ([Add09], [EHH+08], [SLJ+05], [JLNS07], [NJN07], [LS08], [Lan08], [SW05]). In other publications, further evaluation approaches can be found ([AS08], [Gam07], [JJSU07], [Wit07]). Some of the more sophisticated and recently released methods from academia will be described briefly below.

2.1 Failure Propagation

Five metrics for the calculation of failure propagation in applications and application landscapes can be found in [Lan08]. Results of the metrics' evaluation are presented in [LMP08]. The *testability* of an application is studied in [LS07].

Lankes [LS08] presents a proposal to preserve quality (e.g. regarding the availability of applications) in a landscape. To this purpose, the failure propagation within an application landscape is investigated. This investigation relies on the fact that connected applications are interdependent. An application relies on data and/or services provided by another application. This interwoven structure causes (even transitively) connected applications to operate incorrectly if an application fails or is behaving erroneously.

The presented approach also takes failure propagation within a single application into account. By using the software architecture, the interfaces of an application that are connected internally can be specified, so that the failure propagation from required interfaces to provided interfaces of an application can be evaluated. For this purpose, specific data as well as metrics that can make use of the data are required.

2.2 Business Value Assessment

In [Gam07], a method is introduced by which stakeholders of an enterprise can decide on alternatives (denoted as *System Scenarios*) in an upcoming IT investment. The enterprise is enabled to take a justified decision in favor of the system scenario which is capable of generating the greatest business value.

The method allows for a comprehensive examination and evaluation of an application landscape (i.e. the different system scenarios), including different points of view. Several assessments of each system scenario are obtained by people in charge, experts, and intended users.

Uncertain results from evaluations by humans are handled by the presented method. Furthermore, the percentage of fulfillment of functional and non-functional properties of a given scenario is stated. An additional range reflects the uncertainty and incompleteness in the experts' answers.

Such a method can be applied whenever experts' assessments are required in order to compensate for missing information.

2.3 Enterprise Architecture Analysis

Simonsson et al. ([SLJ$^+$05]) present an approach to weigh different scenarios against each other and to decide in favor of the best solution available. According to [SLJ$^+$05] the approach is cost-effective, easy to understand and scenario-based. On the basis of easily measurable system properties identified in literature, scenarios are compared to each other.

The presented approach provides an enterprise's CIO with comprehensible information to support the decision making process.

In order to balance investment alternatives, the analysis of the different systems' qualities is emphasized. Desirable quality attributes are, amongst others, availability, safety, functional suitability or interoperability. In [JJSU07], a software tool is described that supports the user in the creation of enterprise architecture models and their analysis regarding the desired quality attributes. Several quality attributes as well as some metrics that are relevant to the analysis of a system's quality are mentioned in [JLNS07] and [NJN07].

3 Approach for classifying metrics and key figures

To achieve a categorization of key figures and metrics we introduce a method which allows for a comparison of different key figures. To provide a structured overview of key figures and metrics, for each key figure a table is created, providing an overview of the most relevant data. The table is similar to the key figure template introduced in [Küt09]. An example is presented in Table 1.

Key Figure #00	1.0(1) | [x,y] | $\mathbb{AL}$
Name	Name of the key figure.
Description	A short description of the key figure.
Use	What is assessed by the key figure?
Required Data	Which kind of data is required to determine the key figure by a metric?
Metric	The metric used to calculate the key figure's value.

Table 1: Template for the key figure overview table

This table contains relevant information about a key figure. First of all, the name and a brief description are given. Whenever both those entries are not sufficient to explain the key figure's usage, the additional field "use" can be filled in to provide further information. Since every key figure is based on concrete data, this information is also part of the table, in the row labeled "required data". CIOs or other stakeholders may see with a quick glance which data has to be acquired to use the key figure.

This is quite an important aspect, since information gathering usually is time-consuming and thus expensive. Organizations in general do not have all required information at their disposal. It may either not have been collected at all or may be outdated. Thus, the objective to use a key figure might be connected with some effort which is made evident by the key figure overview table.

The last textual information in the table is a (formal) description of the underlying metric that has to be applied to compute the key figure's value. Equation 1 presents an exemplary metric (metric for key figure *service availability*). The variables in the metrics have to be explained clearly in the "required data" section (cf. Table 3).

$$sA(oi) = \sum_{j \in I(oi)} A^{|j|}(1-A)^{\#app-|j|} \tag{1}$$

Categorizations of key figures are represented by a code located in the upper right corner of the table. That code contains three sections separated by ']': *effort*, *way of comparison of results*, and *evaluation context*. Theses elements are explained in detail in the following.

Effort

The first element indicates how much effort is required to get the key figure's value. The lower the number, the smaller the effort. On the basis of the data required for the computation of the key figure's value, experts ought to estimate the necessary effort.

To determine this, the following steps have to be performed: For each entry in the required data field (cf. Table 1) the data volume has to be identified and assigned to one of the following categorization classes: *small*, *medium*, or *large*.

Moreover, the complexity of gathering the required data has to be figured out. The complexity can be assigned to either *easy*, *medium*, or *hard*. If the amount of data can be gathered automatically, the complexity is ranked as *easy*. There might be tools in the organization that hold the required data and no further manual processes to collect information have to be performed. For instance data about the *availability* of applications could be required, which is continuously checked by a monitoring tool. The complexity is regarded as *medium* whenever manual interventions are needed, for instance when automatically collected data has to be checked and filtered manually. If the required data is not available in digital form at all and it has to be collected manually, we define the complexity to be *hard*.

There are nine possible combinations of data volume and complexity of data collection that describe the effort (cf. Table 2). These combinations are named as (effort) *classes*. We define five different effort levels from 1 to 5, where 5 represents the greatest effort. Each effort class is assigned to an effort level. Table 2 visualizes these mappings.

Class	Data volume	Complexity		Mapping
C#1	small	easy	$\longrightarrow$	1
C#2	small	medium	$\longrightarrow$	1
C#3	small	hard	$\longrightarrow$	3
C#4	medium	easy	$\longrightarrow$	1
C#5	medium	medium	$\longrightarrow$	2
C#6	medium	hard	$\longrightarrow$	4
C#7	large	easy	$\longrightarrow$	2
C#8	large	medium	$\longrightarrow$	4
C#9	large	hard	$\longrightarrow$	5

Table 2: Mapping of possible combinations of data volume and complexity on numbers.

The cumulative effort which has to be carried out to get all required data for the key figure is the result of the arithmetic mean of the classes assigned to each entry in the "required data" field. This result is rounded to one decimal place.

Although the average effort value might indicate a moderate effort, there could be some required pieces for which data acquisition effort is particularly high. To express such peaks, a second key figure can be assigned to the effort level. This key figure represents

the highest effort level for all sorts of required data and is shown in round brackets, next to the mean value. Hence an effort of 2.0(5) might imply more difficulties in data acquisition than an effort of 2.0(3).

Comparison of results

The second code element describes how results for the respective key figure can be compared. If the key figure is a number, the result range can be split into intervals. That is depicted by the term $[x, y]$. For each key figure the variety of assessment intervals has to be predefined, that is the number of intervals as well as their boundaries.

If a key figure's value is an element of a set of discrete concepts, the respective code contains the term $\{x_1, \ldots, x_n\}$. Similar to the classification into assessment intervals, the discrete result sets have to be predefined. According to the definition of a key figure ([Küt09]) they have to be measurable on a scale. Thus, only elements within the defined set are valid and each element of the set is mapped to a number (for additional information see [Gri09]).

Evaluation context

One of the three symbols $\mathbb{AL}$, $\mathbb{L}$ and $\mathbb{A}$ appears in the third and last element of the code. The symbol $\mathbb{AL}$ represents key figures that can be used for context-dependent evaluations of applications. Key figures that describe landscape properties are illustrated by a $\mathbb{L}$. The third group (depicted by a $\mathbb{A}$) contains the key figures that are targeting application properties. The key figures of the last two groups ($\mathbb{L}$ and $\mathbb{A}$) do not represent indicators that consider the actual context of applications, that is for instance respective landscape with all the interdependencies to connected applications (cf. [AS08], [Add09]). However, the key figures of all three groups will provide valuable information about the landscape to the CIO.

4   Results

Performing the literature research, we identified 64 key figures in the investigated literature (cf. [Add09], [EHH$^+$08], [JLNS07], [Lan08], [NJN07], [SLJ$^+$05], [SW05], [Wit07]). These were classified using the proposed methodology (cf. section 3). Table 3 presents the key figure *serviceAvailability* ([Lan08]) as a concrete example that is deemed representative of the others.

In addition to the examination of the key figures we also took a closer look at the required data. Altogether 108 different types of data are needed to calculate the 64 key figures' values (after removal of duplicates).

Key Figure #1	2,3(4) │ [x,y] │ $\mathbb{AL}$
Name	serviceAvailability (sA)
Description	The key figure indicates the percentage of cases in which an interface oi is available. A "case" is a state of an application landscape (cf. [Lan08]).
Use	-
Required Data	• The set $I(oi)$, containing the states of an application landscape in which the respective interface is available. [C#3, C#6] • The availability A of the interface's oi application. [C#1] • The set $\#app$ of applications that are part of the application landscape under investigation. [C#1]
Metric	$$sA(oi) = \sum_{j \in I(oi)} A^{|j|}(1 - A)^{\#app - |j|}.$$

Table 3: Key Figure #1: serviceAvailability

The data can be roughly divided into two main categories, *numeric*, i.e. countable and *categoric*, i.e. non-countable data. Numeric data is data like the *total number of applications in a landscape.* The categoric category summarizes data like the *software architecture of an application.* The group of numeric data contains 71 types of data (66%). 37 types of data (34%) relate to the categoric category. These two main categories were further refined. Each of them is divided into four sub-categories: *Intra-A/AL*, *Environment-A/AL*, *Key Figures* and *Detached Data* (cf. Figure 1). The diagram shows the distribution percentage of all data over the four sub-categories.

The group Intra-A/AL contains data that represents information about an application (A) or a landscape (AL), for instance the *number of modules per system.* This group accounts for a share of 55% of all data, numeric and categoric. Data that represents information about the operating environment of an application or an application landscape (e.g. *number of users of an application*) is collected in the group Environment-A/AL, which accounts for a share of 21%. If required data itself is again a key figure, such as the *coupling of pair wise considered applications*, it is assigned to the appropriate category, which accounts for a share of 9%. The remaining 15% of the data focuses on data that can be collected without taking a specific application or a landscape into account. Therefore it is summarized in the category Detached Data. Some kinds of arising costs are collected in this group. Altogether there are eight categories. The exact distribution of the data into these categories is presented and explained in [Gri09].

The effort estimation introduced in section 3 allows for the comparison of different key figures. If the data types required for calculating a key figure are known, it is easy to determine the effort by using the presented approach. The calculation of the effort is based on data types and not on actual data. That is why an instance-independent value is generated. Together with the suitability of a key figure for the evaluation of applications in the context of their landscape a simple way of comparing key figures is achieved. Figure 2 depicts the key figure distribution of the two categories effort and suitability for application landscape assessment.

The effort scale ranges from 1 to 5. For 41% of all key figures, the respective effort is
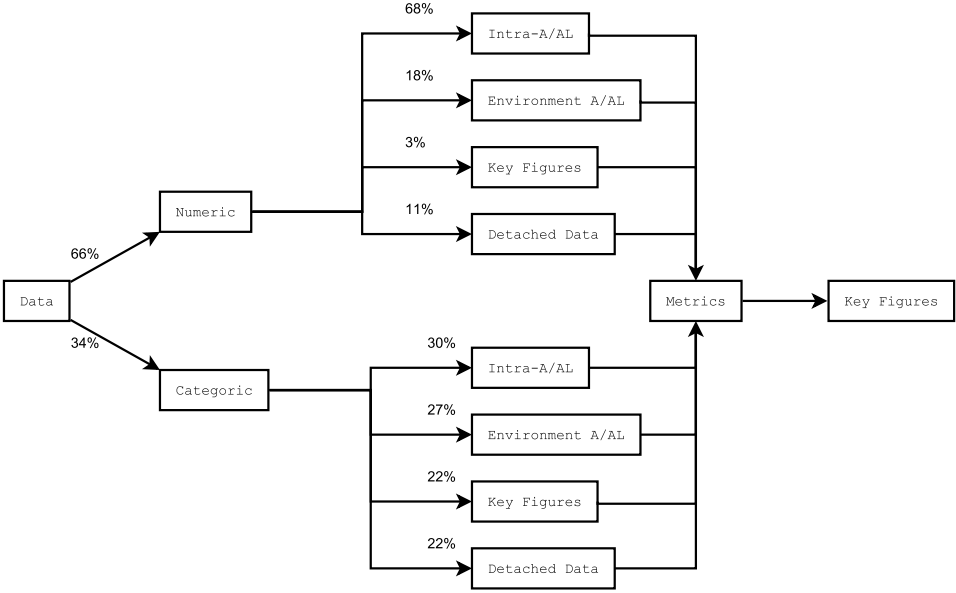
Figure 1: Distribution of all data on the different categories and sub-categories.

less than 1.5 (cf. Figure 2, left side). These key figures can be calculated easily and relatively quickly. This is of interest, if a quick overview of the application landscape under investigation is desired. Nevertheless, the given number may vary from organization to organization due to the heterogeniety of existing data. The diagram on the right in Figure 2 shows how many key figures are suitable for context-dependent evaluation of application landscapes (8%) and how many key figures are appropriate for assessing landscape properties (53%) and application properties (39%) respectively.
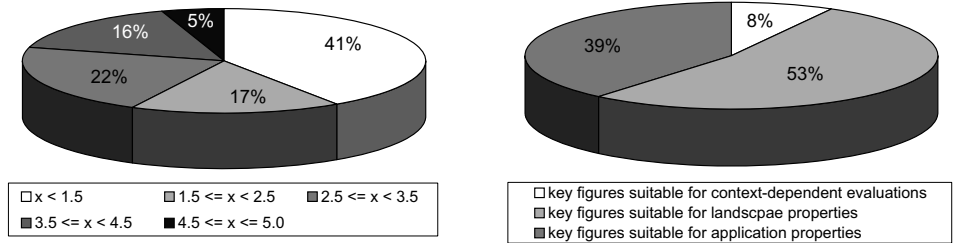

Figure 2: Distribution of effort (left) and suitability for application landscape assessment (right).

Due to the limited space of this contribution, we can only take a quick glance at our results and refer to [Gri09] which contains more detailed explanations as well as categorizations of all 64 key figures and further diagrams.

For the key figures' computation, the required data not only has to be collected but also its

topicality as well as correctness have to be assured. This is achieved through a continuous maintenance of data. The provision of necessary data is one of the largest challenges. To meet this challenge and the demand for faster and easier computation of key figures it is desirable to have this task supported by a software tool.

A central EA management cannot be assumed for all companies and thus not all relevant data is available quickly. Frequently crucial data is clustered in an employee's individual files, or is not available in digital or even written form (expert knowledge). In some situations it is not (yet) possible to do without the opinion of experts.

In order to draw the right conclusions from an application landscape's evaluation, an analysis should be done to identify the key figures to be used. Then the recommended key figures are computed. Despite the previous analysis, a subsequent interpretation of the results by experts is essential.

5   Usage of Application Landscape Metrics

To this stage no tools are available, which allow for a flexible usage of landscape metrics to evaluate an application landscape and thus support IT management processes. Therefore, we implemented a "lightweight" assessment tool which enables the inclusion of various kinds of metrics as a prototype. The tool relies on the Eclipse Rich Client Platform and thus allows for the inclusion of plugins to extend the software. To be highly flexible, we have built

- plugins to represent metrics,
- plugins to represent results of the evaluations, and
- plugins to contain the data model.

The first kind of plugin allows us to add, remove or modify metrics without changing the software itself. The second kind allows for exchanging the representation of the results, which are constituted of the applications examined and of the key figures of the selected metrics for each application. Thus, it is possible to get a tabular representation as well as a graphical representation of the results.

Figure 3 shows a screenshot of our prototype. While the left area of the screen contains a list of all applications and a list of all integrated metrics, the right area contains the elements of a landscape evaluation. In that area, the CIO has the opportunity to select the metrics to use in the evaluation as well as the applications to be evaluated. The latter aspect is based on the selection of a certain landscape view. After executing the evaluation by clicking the respective button, the results are displayed in the bottom area. The kind of visualization depends on the visualization plugins, which are loaded in the starting phase of the software. The screen in Figure 3 shows a graphical representation. The representation depicts all applications as squares containing the application's name. All selected metrics are depicted as symbols (in this example crosses, rectangles, and circles) with the resulting key figure next to the corresponding application.

Figure 3: Screenshot of our metrics tool-prototype

This visualization is intended to support CIOs at architectural decisions by presenting the quality of applications regarding the selected metrics. Since metrics are defined as plugins, these can easily be added or removed, without modification of the tool itself. All included metrics are listed in the metrics overview window. Beside the metrics' names, the list also contains the complexity classifications (cf. section 3), the key figure objectives (cf. Figure 2), and the classification of the key figure with regard to the taxonomy described in section 3. All this information must be specified in a proprietary XML-file as part of the plugins. In future versions of the software this list is intended to also present the percentage of required data so that the CIO can decide not to use a metric, if the required data is unavailable.

We prototypically implemented three concrete metrics: availability (cf. [Gri09]), technology heterogeneity (cf. [Gri09]), and BIO (business information object) criticality (cf. [Add09]). The first and the last metric require information about the landscape structure, since the metrics' definitions use the connections between applications for the computation; the second one compares the technology of an application with the technology of the other applications. Detailed explanations are presented in [Gri09]. These metrics are landscape metrics since they cannot be applied to a single application without taking into account further artifacts.

6   Conclusion and Outlook

We have presented a categorization method for key figures resulting from landscape metrics. The categorization gives an overview of them and makes them comparable regarding the effort of collecting the required data. The structure of the key figure presentation allows for estimation of the trade off between data gathering effort and benefit of the key figures' values.

This categorization method was applied to the results of a literature research that aimed at identifying metrics and key figures which can be used to evaluate landscapes and applications regarding their EA context, for instance their dependencies to other artifacts. 64 key figures were identified in literature. To apply the metrics in order to get the key figures' values, data is required. Along with the results, 108 different types of data were identified and presented in the key figure overview tables (cf. example in Table 3).

To give a brief demonstration of how to use the various metrics and key figures, we have presented a prototypical tool which uses a modular architecture to provide extensibility towards metrics, the underlying data model, and the result presentations.

One plan for future activities is to refine and improve the categorization by gathering more knowledge about the actual amount and the actual complexity of required data. The effort's estimation may rely on empirical values instead of experts' estimations. In order to receive this information, a survey has to be conducted aiming at organizations that already make use of landscape metrics.

In the example scenario we have applied three metrics, thus we have received three key figure values for each application. In order to compare two applications each key figure has to be compared to the according one of the other application. The more metrics are used the more complex the comparisons will get. Additionally the metrics may have different weighting factors that also have to be taken into account. To improve the usage with respect to this aspect, a method to aggregate key figures to receive a single summarizing indicator for an application is required.

References

[Add09]   Jan Stefan Addicks. Enterprise Architecture Dependent Application Evaluations. In *Proceedings of the 3rd IEEE International Conference on Digital Ecosystems and Technologies (IEEE Dest 2009): Cyber Engineering and Creating Value by Making Connections*, Istanbul, 2009.

[AS08]   Jan Stefan Addicks and Ulrike Steffens. Supporting Landscape Dependent Evaluation of Enterprise Applications. In Martin Bichler, Thomas Hess, Helmut Krcmar, Ulrike Lechner, Florian Matthes, Arnold Picot, Benjamin Speitkamp, and Petra Wolf, editors, *Multikonferenz Wirtschaftsinformatik, MKWI 2008, Proceedings: [26. - 28. Februar 2008, TU München in Garching]*, pages 1815–1825. GITO–Verlag, Berlin, Berlin, 2008.

[Dur06]   Michael Durst. Kennzahlengestütztes Management von IT-Architekturen. In Hans P. Fröschle and Susanne Strahringer, editors, *IT-Governance*, volume 250 of *HMD*, pages 37–48. dpunkt-Verl., Heidelberg, 2006.

[EHH⁺08] Gregor Engels, Andreas Hess, Bernhard Humm, Oliver Juwig, Marc Lohmann, Jan-Peter Richter, Markus Voß, and Johannes Willkomm. *Quasar enterprise: Anwendungslandschaften serviceorientiert gestalten*. dpunkt.verlag GmbH, Heidelberg, 1. aufl. edition, 2008.

[FP98] Norman E. Fenton and Shari Lawrence Pfleeger. *Software metrics: A rigorous and practical approach*. PWS Publ., Boston, 2 edition, 1998.

[Fra02] Ulrich Frank. Multi–perspective enterprise modeling (MEMO) conceptual framework and modeling languages. *Proceedings of the 35th Annual Hawaii International Conference on System Sciences, 2002. HICSS*, pages 1258–1267, 2002.

[Gam07] Magnus Gammelgaard. *Business Value Assessment of IT Investments: An Evaluation Method Applied to the Electrical Power Industry: Dissertation*. PhD thesis, Royal Institute of Technology (KTH), Stockholm, 2007.

[Gri09] Philipp Gringel. *Metriken zur Bewertung von Anwendungslandschaften*. Diplomarbeit, Carl von Ossietzky Universität, Oldenburg, 2009.

[GSL07] Magnus Gammelgaard, Marten Simonsson, and Åsa Lindström. An IT management Assessment Framework: Evaluating Enterprise Architecture Scenarios. *Information Systems and E-Business Management*, 5(4):415–435, 2007.

[Jam08] Greta A. James. Magic Quadrant for Enterprise Architecture Tools, 2008.

[JJSU07] Pontus Johnson, Erik Johansson, Teodor Sommestad, and Johan Ullberg. A Tool for Enterprise Architecture Analysis. In *Proceedings of the 11th IEEE International Enterprise Computing Conference (EDOC 2007)*, October 2007.

[JLNS07] Pontus Johnson, Robert Lagerström, Per Närman, and Mårten Simonsson. Extended Influence Diagrams for System Quality Analysis. *Journal of Software*, September 2007.

[Kel07] Wolfgang Keller. *IT–Unternehmensarchitektur: Von der Geschäftsstrategie zur optimalen IT-Unterstützung*, volume 1. dpunkt.Verl., Heidelberg, Neckar, 1. aufl. edition, 2007.

[KKC00] Rick Kazman, M. Klein, and Paul C. Clements. ATAM: Method for Architecture Evaluation, 2000.

[Küt09] Martin Kütz. *Kennzahlen in der IT: Werkzeuge für Controlling und Management*. dpunkt.verlag GmbH, Heidelberg, 3 edition, 2009.

[Lan05] Marc M. Lankhorst. *Enterprise Architecture at Work: Modelling, communication, and analysis*. Springer, Berlin, 2005.

[Lan08] Josef Lankes. *Metrics for Application Landscapes: Status Quo, Development, and a Case Study: Dissertation*. PhD thesis, Technische Universität München, München, 2008.

[LMP08] Josef Lankes, Florian Matthes, and Tarmo Ploom. Evaluating Failure Propagation in the Application Landscape of a Large Bank. *Comparch 2008 Industrial Experience Report Track, Karlsruhe*, 2008.

[LS07] Josef Lankes and Christian M. Schweda. Constructing Application Landscape Metrics: Why & How. Garching b. München, 2007.

[LS08]   Josef Lankes and Christian M. Schweda. Using Metrics to Evaluate Failure Propagation and Failure Impacts in Application Landscapes. In Martin Bichler, Thomas Hess, Helmut Krcmar, Ulrike Lechner, Florian Matthes, Arnold Picot, Benjamin Speitkamp, and Petra Wolf, editors, *Multikonferenz Wirtschaftsinformatik, MKWI 2008, Proceedings: [26. - 28. Februar 2008, TU München in Garching]*, pages 1827–1838. GITO–Verlag, Berlin, Berlin, 2008.

[MBLS08] Florian Matthes, Sabine Buckl, Jana Leitel, and Christian M. Schweda. Enterprise Architecture Management Tool Survey 2008, 2008. Technische Universität München, Chair for Informatics 19 (sebis).

[NJN07]   Per Närman, Pontus Johnson, and Lars Nordström. Enterprise Architecture: A Framework Supporting System Quality Analysis. In *Proceedings of the IEEE International Annual Enterprise Distributed Object Computing Conference (EDOC)*, volume 11, October 2007.

[Pey07]   Henry Peyret. The Forrester Wave: Enterprise Architecture Tools, Q2 2007, (http://www.forrester.com/go?docid=41915), 2007.

[SLJ$^+$05]   Mårten Simonsson, Åsa Lindström, Pontus Johnson, Lars Nordström, John Grundbäck, and Olof Wijnbladh. Scenario-Based Evaluation of Enterprise Architecture - A Top-Down Approach for CIO Decision-Making. In *Proceedings of the International Conference on Enterprise Information Systems*, May 2005.

[SW05]   Alexander Schwinn and Robert Winter. Entwicklung von Zielen und Messgrößen zur Steuerung der Applikationsintegration. In Otto K. Ferstl, Sven Eckert, Tilman Isselhorst, and Elmar J. Sinz, editors, *Wirtschaftsinformatik 2005: EEconomy, eGovernment, eSociety*, Springer-11775 /Dig. Serial], pages 587–606. Physica-Verlag Heidelberg, Heidelberg, 2005.

[Wit07]   André Wittenburg. *Softwarekartographie: Modelle und Methoden zur systematischen Visualisierung von Anwendungslandschaften*. Dissertation, Technische Universität München, München, 2007.

[WS06]   Robert Winter and Joachim Schelp. Reference Modeling and Method Construction: A Design Science Perspective. In M. Lorie, editor, *Proceedings of the 21st Annual ACM Symposium on Applied Computing (SAC2006),*. ACM Press New York, NY, USA, 2006.