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Aiming at Methods' Wider Adoption: Applicability Determinants and Metrics

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Abstract

Numerous computer science methods and techniques have been proposed by the scientific community. However, depending on the domain, only their minor fraction has met wider adoption. This paper brings attention to the concept of applicability – the notion that is well acknowledged in the scientific field but have not been analysed with respect to determinants, metrics and systematisation. The primary objective of the study was to identify applicability determinants and metrics and consolidate them into a taxonomy, based on a systematic process. To achieve the objective, a methodological literature review supported with operationalisation activities were applied. As a result, more than thirty descriptors of applicability were introduced in the proposed applicability taxonomy, and a similar number of metrics has been elicited. Based on them, a questionnaire for evaluation of the method's applicability was created and applied to the evaluation of a currently developed cybersecurity risk assessment method that aims at broader market uptake. The analysis provided indications on its further developments, but also findings of a more universal character.

Keywords: method design, evaluation, determinants, metrics, methods, applicability, usability, acceptance, risk assessment, organisational management, cybersecurity management

1. Introduction

The scientific community witnesses multiple new method proposals. Only when introducing the phrase 'new method' into the search engines of scientific databases[1] dozens or even hundreds of thousands of results appear. But how many of the solutions have been applied into practical contexts outside the laboratory settings where they were invented? How many of them are utilised in enterprises, infrastructures or other operational environments? It depends on the field, but usually only a minor fraction. Examples can be provided [1, 2, 3, 4, 5, 6, 7, 8, 9, 10], but the issue is well-known in the scientific community.

The question arises: which factors determine that certain methods are applied and other not? Analysis of the literature shows that, while the notion of 'applicability' is utilised commonly, no attempts have been made to analyse it with respect to determinants, metrics and systematisation. The paper aims at filling the gap by operationalising the concept of applicability, identifying the applicability factors, integrating them into a taxonomy and introducing evaluation metrics. In addition, a dedicated questionnaire for evaluating methods' applicability was developed in a systematic manner that strongly builds upon existing, standardised-questionnaires from the usability field.

In a practical dimension of the research, the results were utilised in the evaluation of a currently developed risk assessment method that aims at wide adoption. Based on them, a survey was designed and carried out among 42 participants that had earlier undergone the method's learning and application process. The evaluation provided concrete indications as far as its further developments are concerned. The outcomes specific to the method are out of this paper scope, but the findings that have a more universal character are presented in this paper. The research does not aim to be comprehensive. Rather than that, it is intended as an initial contribution to open up a discussion on the practical applicability of scientific proposals.

The paper is organised as follows. In the next section, related works are discussed. In Section 3, the operationalisation of the applicability concept is explained. Section 4 presents the identified applicability determinants and the proposed taxonomy. The developments on the questionnaire for methods' evaluation are demonstrated in Section 5. Section 6 describes the practical application of the research outcomes to the evaluation of a risk assessment method. Finally, the paper ends with concluding remarks.

2. Literature study

2.1. Review method

A literature review that aimed at identifying alternative studies that provide metrics or determinants of applicability was performed in June 2020. The survey adopted the guidelines of Webster and Watson's [11] as well as Kitchenham and Brereton [12] on conducting systematic literature reviews. The literature was sought in recognised scientific databases including the ACM Digital Library, Elsevier ScienceDirect, Emerald, IEEE Xplore, Oxford Journals, Springer, Taylor & Francis, Wiley and the Web of Science aggregative database. When identified papers referred to other relevant papers, also the papers were introduced to the analysis (*backward analysis* [11]).

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[1] such as the ACM Digital Library, Elsevier ScienceDirect, Emerald, IEEE Xplore, Oxford Journals, Springer, Taylor & Francis or Wiley

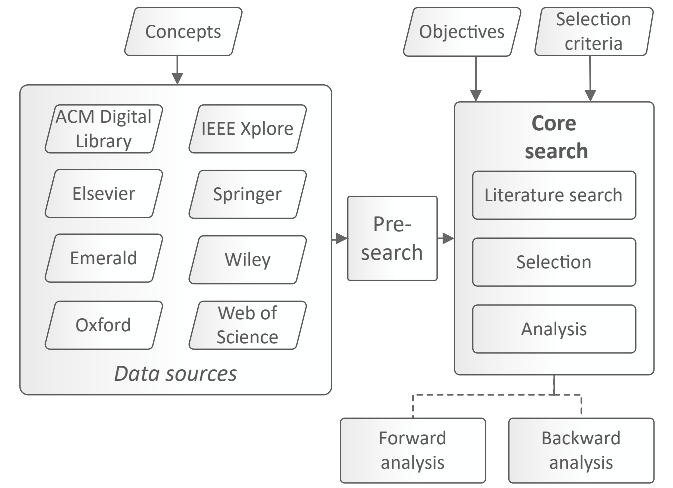

Figure 1: The key tasks and data sources employed during the review process.

The key stages of the literature review together with utilised main data sources are presented in Figure 1. As a first step (in Figure depicted as 'pre-search') for orientation, the general search term 'applicability' was applied. The term was looked for 'anywhere' or in 'all fields'. This was followed by a core search that comprised three principal components, i.e. the literature search, selection and analysis. During the *literature search* the documents' sources were looked through using phrases 'applicability determinants' (or 'applicability AND determinants' where possible) and 'applicability metrics' (or 'applicability AND metrics' where possible). Several iterations were performed to narrow down the number of results. Depending on the capabilities of the search engines, the initial iterations focused on titles, abstracts, keywords or other metadata. Then, the descriptions of the publications were read (*manual search*), to finally browse the contents of the documents in the concluding iteration (*in-depth analysis*). Applied selection (inclusion) criteria comprised English documentation, presence of applicability metrics or determinants descriptions in the content and the relevance to computer science or a cognate domain. In the *literature analysis* stage, the documents were read partially or entirely to identify knowledge about applicability factors. The most remarkable contents were highlighted and copied to a separate summary document (*data extraction*) for further analysis.

2.2. Results

Unsurprisingly, very large numbers of results were obtained during the 'pre-search' phase. For instance, 113,124 in the ACM Digital Library, 1,762,122 in Elsevier ScienceDirect, 423,777 in Springer, or 227,919 in Web of Science. This is especially because the search engines transformed the term into its declinational forms including such popular words as 'application' or 'applied'. Moreover, the rough analysis of results revealed that the majority of them concerned discussions on the application of a proposed solution to a particular domain [13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26].

The results of the core search are summarised in Tables 1 and 2. Three papers [27, 28, 29] were identified as potentially relevant as they mention determinants or metrics in the context of applicability. The papers became subject to content analysis.

The research of Hong et al. [27] is dedicated to graphical security models. After introducing a comprehensive taxonomy of the solutions, the authors discussed certain aspects related to their application. Namely, they identified the most used cybersecurity metrics utilised by the models and recognised supporting tools reported and made available to the public. Also, application domains were recognised. An important part of the paper is devoted to analysing the complexity of the models. Mainly in connection to it and the efficiency, the usability of models is briefly discussed.

Lantow and Sandkuhl [28] researched the applicability of ontology quality metrics to content ontology design patterns. The study comprised two main parts. The first stage regarded the verification whether the metrics retained their differentiating capabilities when applied to the new domain. The second part aimed at comparing the quality indicators obtained with the metrics to the perceptions of quality provided by ontology engineers. According to the authors, quality is an essential factor for the acceptance of technologies and solutions and usability of products.

Ling et al. [29] research the use of information technologies among school educators in Malaysia. Technology acceptance models are applied for this purpose, namely the Unified Theory of Acceptance and Use of Technology model (UTAUT) and the Technology Acceptance Model (TAM). Based on comparative analysis of the frameworks performed by the authors the UTAUT model was selected for analysing the situation in Malaysia.

It becomes evident that while the papers mention metrics or determinants in the context of applicability, the metrics and determinants are not directly connected to applicability. Moreover, the studies focus on particular application domains (graphical security models, ontology design patterns and the usage of information technologies among school educators). On the other hand, they constitute a valuable input to this research, indicating complexity and usability as potential areas where applicability can be measured [27, 28] and acceptance as its prospective determinant [29, 28]. Although the term 'applicability' is commonly used in the scientific literature, an analysis in regard to its potential metrics, determinants and systematisations has not been performed.

3. Operationalisation of the applicability concept

To identify the main concepts on which applicability is based i.e. the variables that can be measured, also called *descriptors*, the approach of Saris [30] was adopted. According to the approach, which derives from the deductive theory, moving from complex concepts to their descriptors (questions) is called *operationalisation* [30]. This can be done in a three-step process in which [30]:

- the complex concepts (*concepts-by-postulation*, or *constructs*) are defined using *concepts-by-intuition* i.e. the

Table 1: Summary of the literature search for applicability determinants.

Source	Everywhere, exact phrase*	Title	Abstract	Keywords	Content analysis
ACM DL	0	0	671	0	0
Elsevier SD	2	0	737		0
Emerald	0	1	51	n.a.	0
IEEE Xplore	0	0	35	0	1
Oxford Journals	176	588	n.a.†	0	0
Springer	0	0	n.a.	n.a.	0
Taylor & Francis	0	30	n.a.	1	0
Wiley	0	65	11129	4	0
WoS‡	0	6	n.a.	1253	0
Total	178	690	12623	1258	1

* The search started with 'anywhere' or 'all fields', but the results embraced also declinations of the word 'apply', such as 'application' or 'applied', which were not relevant to the topic of the study. Narrowing the search was necessary.

† Although a very large number of results was reported in this abstracts' search, manual analysis revealed that there were no instances of the searched keyphrases in the abstracts.

‡ Search results partially repeated findings from searches in other databases.

Table 2: Summary of the literature search for applicability metrics.

Source	Everywhere, exact phrase*	Title	Abstract	Keywords	Content analysis
ACM DL	4	6	612	1	0
Elsevier SD	132	9	1583		1
Emerald	1	0	47	n.a.	0
IEEE Xplore	1	11	797	0	0
Oxford Journals	24	18	n.a.†	0	0
Springer	10	0	n.a.	n.a.	0
Taylor & Francis	0	0	n.a.	0	0
Wiley	5	1	565	0	1
WoS‡	1	40	n.a.	3109	0
Total	178	85	3604	3110	2

* The search started with 'anywhere' or 'all fields', but the results embraced also declinations of the word 'apply', such as 'application' or 'applied', which were not relevant to the topic of the study. Narrowing the search was necessary.

† Although a very large number of results was reported in this abstracts' search, manual analysis revealed that there were no instances of the searched keyphrases in the abstracts.

‡ Search results partially repeated findings from searches in other databases.

concepts for which straightforward metrics (obvious questions) can be formulated,

- concepts-by-intuition are transformed into statements indicating the requested concept,
- the statements are transformed into metrics (questions).

Two main types of operationalisation were distinguished. In the *operationalisation using formative indicators*, a concept-by-postulation is decomposed into other concepts (*formative indicators*) that are causes of the phenomenon described by the concept-by-postulation. To obtain a complete measurement, it is important to identify all formative indicators. In the *operationalisation using reflective indicators*, the complex concept is decomposed into *reflective indicators* i.e. the consequences of the phenomenon described by the complex concept. Causal relationships have opposite direction than in the case of formative indicators [30].

As this research is focused on identifying the determinants of applicability, the operationalisation using formative indicators was applied. The activities of operationalisation process are presented in Figure 2.

To identify the concepts-by-intuition for the notion of 'method applicability', the dictionary definitions of 'applicability' were firstly analysed. The oldest definition comes from Webster's Revised Unabridged Dictionary [31], where applicability is specified as the quality of being applicable or fit to be applied [31]. More recently, Babylon NG [32] refers to applicability as to the suitability, ability to be implemented. Collins English Dictionary [33] defines the word 'applicable' or 'appliable' in British

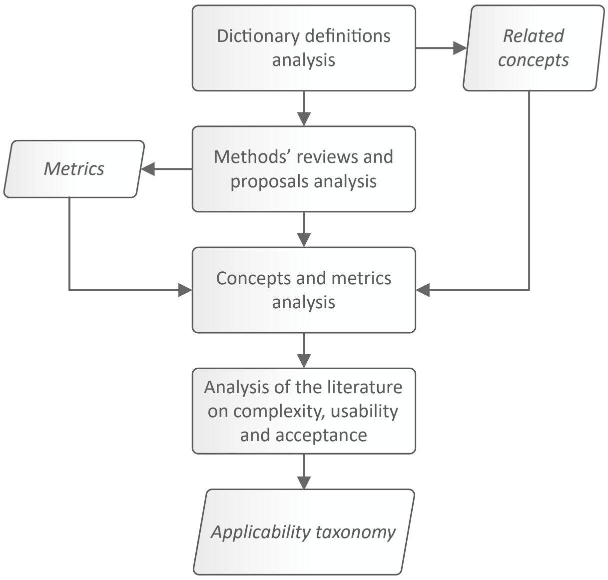

Figure 2: The activities of operationalisation process of the applicability concept.

English as being able to be applied, fitting, appropriate or relevant [33], while Longman Dictionary of Contemporary English [34] states that if something is applicable to a particular person, group, or situation, it affects them or is related to them.

The second step was the analysis of the literature with methods' reviews, methods' proposals and potentially their application descriptions in search for applicability factors and metrics. Aiming at the feasibility and rational time boundaries for the process, but also due to the good familiarity with the area, the analysis was initially focused on risk assessment methods and reviews [35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53] and later extended to other referrenced publications (backward analysis, see Section 2.1). The literature was identified in the process analogous to one described in Section 2.1. The literature was sought primarily in journals and books, in the databases of established publishers that address the topics of information security, communication systems, computer science and similar, namely the ACM Digital Library, Elsevier, Emerald, IEEE Xplore, Springer and Wiley. Then, it was followed by the search in aggregative databases that store records of various publishers – EBSCOhost, Scopus and Web of Science. Additionally, the search was complemented with a short search of conference proceedings and the Internet. During the literature search stage, the documents' sources were looked through using keywords such as "cybersecurity assessment", "review", "survey" or "method". Special attention was given to evaluation criteria described in the resulting publications because they might become potential candidates for applicability metrics. As applicability is connected to complexity, usability and acceptance [27, 28, 29] (see the previous Section) the literature related to these notions was analysed regarding connected concepts [54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 29]. Table 3 visualises the concepts identified in particular publications. Finally, the applicability taxonomy was developed based on the analysis of the extracted applicability factors.

Table 3: Applicability concepts identified in analysed publications.

Pub.	Concepts
[40]	Number of analysts, preparation extensiveness, effort
[52]	Knowledge of the application domain, capability to execute a method, expertise, level of detail, scope width
[59]	Difficulty of understanding
[67]	Perceived usefulness, effort expectancy
[55]	Number of method components, difficulty of creation, difficulty of creation, difficulty of description
[53]	Completeness
[61]	Number of method components
[56]	Cost, number of method components, difficulty of creation, difficulty of creation, difficulty of description
[66]	Difficulty of understanding
[65]	Difficulty of understanding
[68]	Ratio of the task completion rate to the mean time per task
[29]	Facilitating conditions, number and degree of satisfied requirements for the infrastructure supporting the use of the method, perceived usefulness, effort expectancy, social influence
[60]	Difficulty of creation, difficulty of creation, difficulty of description
[47]	Knowledge of the application domain, capability to execute a method, expertise, effort
[54]	Difficulty of creation, difficulty of creation, difficulty of description
[63]	Efficiency, effectiveness, usefulness, number of real problems solved with the method during a year, satisfaction, universality
[62]	Number of actions required to complete a task, ratio of the task completion rate to the mean time per task, the number of tasks completed successfully divided by the total time spent on all the tasks, task success, level of task success, learnability, time on task by trial, number of steps by trial, number of errors by trial, ease of use
[69]	Facilitating conditions, number and degree of satisfied requirements for the infrastructure supporting the use of the method, perceived usefulness, effort expectancy, social influence
[51]	Cost, time, type of experts, expertise, accuracy, simplicity

4. Applicability taxonomy, determinants and metrics

In this section, the applicability determinants and metrics identified during the operationalisation process are described.

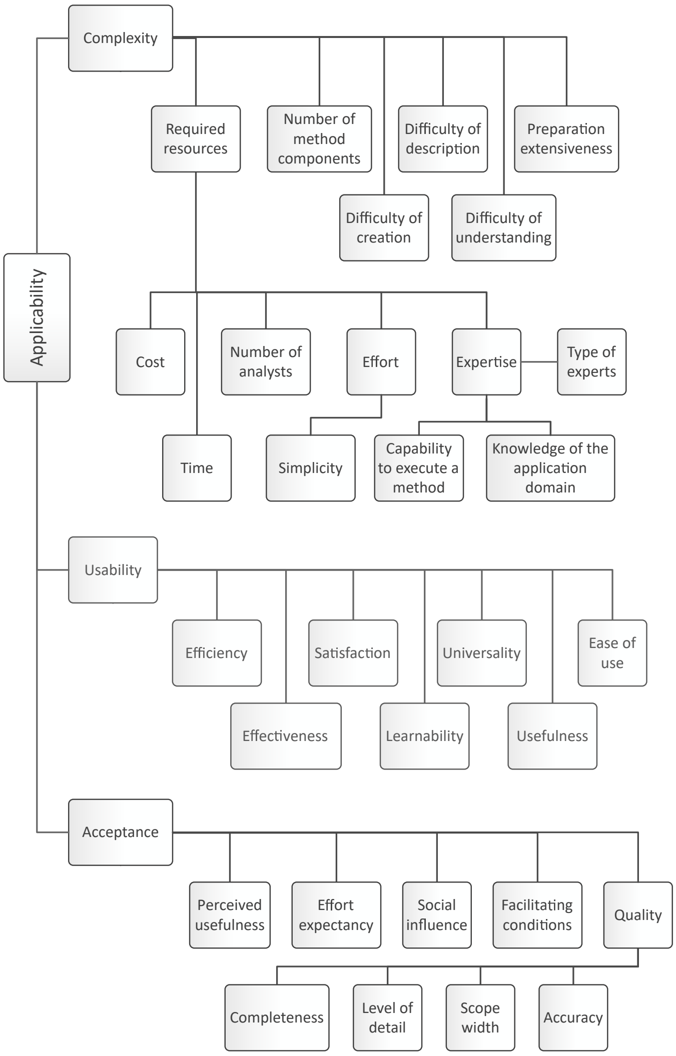

Figure 3: Applicability taxonomy.

The findings were compiled into the applicability taxonomy presented in Figure 3. The primary relationships between the concepts in the taxonomy are generalisation-specialisation relationships. Only in a few cases, when concepts were identified as important to applicability, but there is no direct generalisation-specialisation relationship, another type of primary relationship was indicated. For instance, this is the case of 'type of experts' and 'simplicity' concepts. Simultaneously, the choices were literature-driven i.e. the relationships indicated by the analysed publications were maintained. For the clarity of the taxonomy, only one, the primary relationship between each pair of concepts was illustrated.

For some factors, including the cost, time or the number of analysts, metrics can be directly associated. Thus, they do not require to be designated specifically. For the remaining ones, where applicable, quantitative metrics were provided. Otherwise, the determinants are measured qualitatively. The summary of the metrics is presented in Table 4. The 'qualitative metrics' column of the table could contain also metrics for all the factors from the 'qualitative metrics' column as the quantitative metrics can be converted into qualitative ones by formulating questions on users' opinion or impression on the experience related to the given factor. In the following descriptions, the definitions of the concepts were adapted to the methodology field.

4.1. *Factors associated with methods' complexity*

As far as the literature on complexity is concerned, the following applicability factors were distinguished:

- the *cost* associated with applying the method [51, 56],
- the *time* necessary to successfully apply the method [51],
- *number of analysts* – the number of participants required for the successful application of the method [40],
- the *effort* required to utilise the method [40]; It can be connected to expertise and time required for the method's application [47],
- *expertise* – proficiency required for using the method [51, 47, 52]; According to Paintsil [47], it primarily depends on the capability to execute a method and the knowledge of the application domain,
- *simplicity* – straightforward usage of the method [51].
- *capability to execute the method* – experts' operational capabilities to apply the method [47, 52],
- *knowledge of the application domain* – experts' familiarity with the problem area [47, 52],
- *type of experts* – whether the application can be done by internal participants of requires external experts [51],
- *number of method components* – the number of functionall elements that compose the method [61, 55, 56],
- the *difficulty of creation* – the degree of difficulty associated with constructing or duplicating a method [60, 54, 55, 56],
- the *difficulty of description* – the degree to which a method is difficult to describe [60, 54, 55, 56],
- the *difficulty of understanding* – the degree to which a method is difficult to comprehend [59, 65, 66]; It can be associated with the method's complexity, but also sophistication/simplicity of its description or explanation,
- *preparation extensiveness* – broadness and labour intensity of preparative activities before using the method [40].

Table 4: Quantitative and qualitative applicability metrics. The quantitative metrics can be converted into qualitative ones through the formulation of questions on users' opinion or impression on the experience related to the given factor.

Quantitative metrics	**Qualitative metrics**
Cost [51, 56]	Effort [40, 47]
Time [51]	Expertise [51, 47, 52]
Number of analysts [40]	Simplicity [51]
Type of experts [51]	Capability to execute the method [47, 52]
Number of method components [61, 55, 56]	Knowledge of the application domain [47, 52]
Efficiency [63]:	Difficulty of creation [60, 54, 55, 56]
– number of actions required to complete a task [62]	Difficulty of description [60, 54, 55, 56]
– the ratio of the task completion rate to the mean time per task [62, 68]	Difficulty of understanding [59, 65, 66]
– the number of tasks completed successfully divided by the total time spent on all the tasks [62]	Preparation extensiveness [40]
Effectiveness [63]:	Satisfaction [63]
– task success [62]	Universality [63]
– level of task success [62]	Ease of use [62]
Learnability [62]:	Perceived usefulness [67, 69, 29]
– time on task by trial [62]	Effort expectancy [67, 69, 29]
– number of steps by trial [62]	Social influence [69, 29]
– number of errors by trial [62]	Completeness [53]
Usefulness [63]:	Level of detail [52]
– number of real problems solved with the method during a year	Scope width [52]
Facilitating conditions [69, 29]: – number and degree of satisfied requirements for the infrastructure supporting the use of the method	Accuracy [51]

4.2. Factors associated with methods' usability

The analysis reveals that methods' usability is mainly associated with:

- *efficiency* – the capacity of the method to achieve desired results with appropriate amounts of resources [63]; Most common quantitative metrics of efficiency are the number of actions required to complete a task with the method [62], the ratio of the task completion rate to the mean time per task [62, 68] and the number of tasks completed successfully divided by the total time spent on all the tasks [62],

- *effectiveness* – the capability of the method to achieve desired results with accuracy and completeness [63], the associated quantitative metrics are the task success that can be measured as a binary value (the goals were achieved or not) or graded one (the level of task success) [62],

- *satisfaction* – subjective opinions of experts regarding their impressions on using the method [63],

- *learnability* – the time and effort required to become proficient in using the method [62]; learnability can be measured quantitatively by collecting the data on performance metrics from multiple trials. The multiplexed measurement is essential to observe the change in the users' experience achieved during the learning process. Performance metrics utilised for evaluating learnability include the time on task, number of steps to complete a task or the number of errors during the task realisation [62]. Learnability, similarly to the difficulty of understanding, is connected to the method's complexity and the sophistication/simplicity of its description or explanation,

- *universality* – the method's capacity to accommodate a diversity of users with different experience, knowledge and expertise [63],

- *usefulness* – the method's capability to solve real problems in an acceptable way, it implies practical utility the method [63], a quantitative metric of this attribute can be, for instance, the number of real problems solved with the method during a year,

- *ease of use* – the effort required to utilise the method [62].

4.3. Factors associated with methods' acceptance

Acceptance can be connected with the following factors:

- *perceived usefulness* – the users' subjective perception of the likelihood that using the method will increase their performance within a specific context [67, 69, 29],

- *effort expectancy* – the users' expectation of the effort required to utilise the method [67, 69, 29],

- *social influence* – the users' perception of the importance that others assign to them using the method [69, 29],

- *facilitating conditions* – the degree to which users believe that an organisational and technical infrastructure exists to support the use of the method[69, 29]; an attempt to express the value quantitatively could be to define the requirements for the organisational and technical infrastructure and measure the degree to which they are satisfied,
- *completeness* – whether the method comprehensively tackles the entire addressed problem [53],
- *level of detail* – the precision with which the method approaches the addressed problem [52],
- *scope width* – the broadness of the application domain [52],
- *accuracy* – the precision of results obtained with the method [51].

5. Applicability evaluation questionnaire

Based on the taxonomy and metrics, a questionnaire for evaluation of the method's applicability was created. The development of the questionnaire initiated with a recursive process, where metrics and concepts from the taxonomy were referred to the standardised questionnaires associated with the usability domain [70, 62]. This step aimed at identifying standardised questions that have been successfully used for years to achieve higher initial content validity of the questionnaire [71]. The questionnaires indicated by Tullis et al. [62] and Lewis [64] were analysed:

- After-Scenario Questionnaire (ASQ) [72, 73, 64, 70, 62],
- Computer System Usability Questionnaire (CSUQ) [64, 70, 62, 74],
- Software Usability Measurement Inventory (SUMI) [75, 76, 70, 62],
- System Usability Scale (SUS) [77, 78, 70, 62],
- Post-Study System Usability Questionnaire (PSSUQ) [79, 64, 70, 62],
- Printer Scenario Questionnaire (PSQ) [64],
- Questionnaire for User Interface Satisfaction (QUIS) [80, 62], and
- Website Analysis and Measurement Inventory (WAMMI) [81, 82, 70, 62].

The primary selection criterion for the questions was their adaptability to the methods' domain. Thus, the questions strongly focused on the technical aspects of a solution were excluded. For instance, the Questionnaire for User Interface Satisfaction (QUIS) [80] comprises a substantial component of technically-oriented questions. Another selection criterion for the questions was their compatibility with the metrics and concepts associated with applicability. An effort was put in to achieve a balanced representation of concepts in the questionnaire (around two questions for a concept, see Tables 6 – 9). Also, questions repeated in different questionnaires were considered as priority candidates. Moreover, the type of questions was taken into consideration, with precedence given to closed, scale questions. More than a third of the questionnaire consists of questions from the standardised questionnaires. For the applicability concepts associated with complexity and acceptance, questions were created either based on metrics (whether defined) or defined conforming to the convention of the standardised questionnaires. Tables 6 – 9 demonstrate the questions from the applicability questionnaire together with the related applicability concepts.

Six types of questions were used in the questionnaire:

- 5-grade Likert scale questions (in Tables 6 – 9 denoted as *5LS*) intended for obtaining the level of responder's agreement with a given statement in a 5-degree scale [62]; An example of the question is presented in Figure 4,
- 5-point semantic differential scale questions (marked as *SDS*) – where two opposite opinions are presented at the scale extremes [62]; An SDS-style question is illustrated in Figure 5,
- 10-point linear scale questions (*10PS*) – to measure the extent of a phenomenon [62]; Figure 6 provides an example of the type of question,
- short answer questions (denoted as *SA*) – for which a short answer is expected, such as a value or a phrase,
- longer answer questions (in Tables 6 – 9 marked as *LA*) – enabling responders to provide more descriptive answers, for instance in several sentences,
- PSQ-style questions (denoted as *PSQ*) – questions directly adopted from the PSQ – Printer Scenario Questionnaire [64]; They contain a statement and a choice of seven opinions on that statement. An example of a PSQ-style question is presented in Figure 7.

The validation of the questionnaire is at a preliminary stage. At the moment, the primary content validation of the questionnaire has taken into account that the choices proposed were properly as informed by the literature [71]. Also, calculations related to the test's internal reliability (Cronbachs α coefficients) have been performed. They referred to the compatible 5-grade Likert scale type questions for the main three concepts associated with applicability i.e. the complexity, usability and acceptance. The results are presented in Table 5. The received values, mostly above the 0.7 threshold can be a promising indicator of internal consistency.

6. Evaluating applicability – a case study

The proposed method's applicability questionnaire, extended with supplementary questions presented in Table 10, were ap-

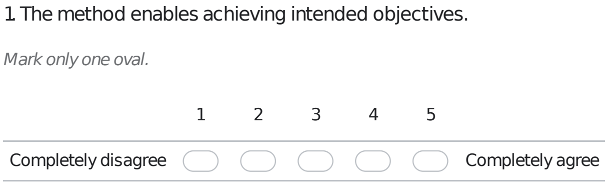

Figure 4: Example of a 5LS – 5-grade Likert scale type of question.

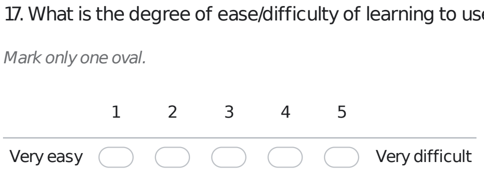

Figure 5: Example of a SDS – 5-point semantic differential scale question.

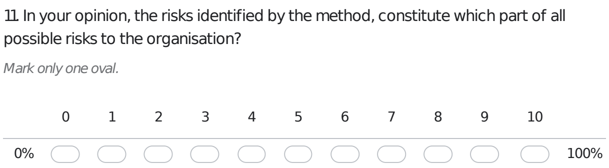

Figure 6: Example of a 10LS – 10-point linear scale question.

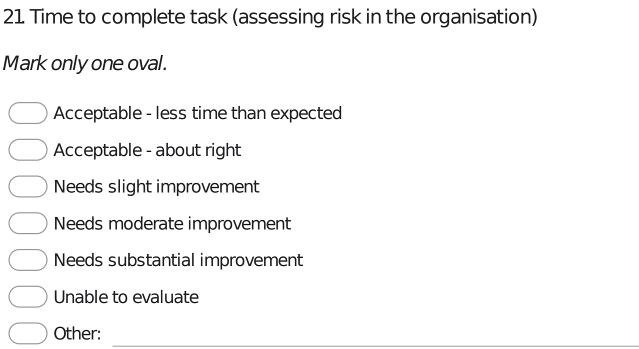

Figure 7: Example of a PSQ-style question [64].

Table 5: Cronbach's α coefficients for 5-grade Likert scale type questions for the main three concepts associated with applicability.

Concept	Questions	Cronbach's α
Complexity	4, 5	0,74
Usability	1, 6, 8, 9	0,82
Acceptance	2, 3, 7	0,69

plied to evaluate the applicability of a cybersecurity risk assessment method. The auxiliary questions were introduced to obtain some additional information concerning the application of the method.

An earlier study evidenced that solutions proposed for this area by the scientific community have not been widely adopted by enterprises. The evaluated method is subject to an iterative process of improvements and adjustments that aims at addressing this issue by assuring a high level of applicability.

In the evaluation, the method was introduced, applied and analysed by the students of the course 'Managing enterprise IT infrastructure and security' delivered in the sixth semester of the Bachelor in Science (engineer degree) interfaculty study program at Gdańsk University of Technology. 42 students, divided into three groups, one from the Faculty of Management and Economics and two from the Faculty of Electronics, Telecommunications and Informatics, participated in the evaluation. During the course, the students first learned the method and then applied it to assess risks in real organisations that they were well familiar with. Around half of the students already had work affiliations and the analyses were based on them.

6.1. Method's description

The evaluated risk assessment method is qualitative. It builds upon the risk formula that is commonly adopted in the cybersecurity domain [83, 84] and defines risk R as a function of the probability (chance of something happening) of the occurrence of an event and the associated consequences [83, 84, 85]:

$$R = f(P, I) \tag{1}$$

The probability P is subjective, based on expert knowledge. It reflects the assessor's degree of belief (uncertainty) of the occurrence of an event [85]. The consequences are expressed qualitatively as the impact I of the event on the organisation (mission, operations, image, or reputation), organisational assets, individuals and other organisations [84].

Risks are assessed in a five-stages process. In the first stage, organisation's information assets are inventoried and evaluated in regard to the impact that the loss of their confidentiality, integrity and availability (the main information security attributes) would have on the organisation. The impact is expressed qualitatively in the form of impact levels (e.g. low, moderate, high). In the second step, all potential threats are identified in a recursive task that aims at achieving the completeness of the resulting list of threats. The threats are *general* in the sense that they are not particularly aimed at the organisation. The 'tailoring' of the threats to the specific organisational context and assets is performed in the third stage. There, the threats are referred to

Table 6: Questionnaire for the evaluation of the method's applicability, *Part 1: Completeness, learnability, time, expertise, the difficulty of understanding – open questions*. Questions are mapped to the related applicability concepts. In round brackets, types of questions are denoted. In this part of the questionnaire only 5LS – 5-grade Likert scale type are used. Where questions were almost directly adapted from standardised questionnaires, the questionnaires are indicated in square brackets.

Satisfaction, completeness, simplicity, effectiveness, accuracy – closed questions	
01. The method enables achieving intended objectives. (5LS) [WAMMI]	Effectiveness [63]
02. The method enables identifying real risks to an organisation. (5LS)	Accuracy [51]
03. The method enables achieving high completeness of results. (5LS)	Completeness [53]
04. The method requires too many steps to get the results. (5LS) [SUMI]	Simplicity [51]
05. The method is too complicated. (5LS) [SUS]	Simplicity [51]
06. Overall, I am satisfied with the method. (5LS) [CSUQ, PSSUQ]	Satisfaction [63]
07. The method has all the functions and capabilities I expect it to have. (5LS) [CSUQ, PSSUQ]	Completeness [53]
08. I will be using the risk assessment method more frequently. (5LS) [SUS]	Satisfaction [63]
09. I would recommend this method for being applied in other organisations. (5LS) [SUMI]	Satisfaction [63]

Table 7: Questionnaire for the evaluation of the method's applicability, *Part 2: Completeness, learnability, time, expertise, the difficulty of understanding – open questions*. Questions are mapped to the related applicability concepts. In round brackets, types of questions are denoted: SDS – 5-point semantic differential scale, 10PS – 10-point linear scale, SA – short answer, LA – longer answer. Where questions were almost directly adapted from standardised questionnaires, the questionnaires are indicated in square brackets.

Completeness, learnability, time, expertise, difficulty of understanding – open questions	
10. What was the total time devoted to using (learning and applying) the method? (SA)	Time [51]
11. What part of that time was devoted to learning the method? (10PS)	Learnability [62]
12. What is the degree of ease/difficulty of learning to use the method? (SDS)	Difficulty of understanding [59, 65, 66]
13. In your opinion, what is the level of competence required to apply the method? (SDS)	Expertise [51, 47, 52]
14. Please, write what is the preferred type of support (a textbook, lecture, practical workshop, individual practice with an expert etc.) that you would like to receive while learning the method? (LA)	Learnability [62]
15. Are you satisfied with the support you received while learning the method? (SDS) [ASQ]	Learnability [62]

Table 8: Questionnaire for the evaluation of the method's applicability, *Part 3: Completion time, ease of use and effort*. Questions are mapped to the related applicability concepts. In round brackets, types of questions are denoted: SA – short answer, PSQ – PSQ-style. Where questions were almost directly adapted from standardised questionnaires, the questionnaires are indicated in square brackets.

Completion time, ease of use and effort	
16. Time to complete task (assessing risk in the organisation) (PSQ) [PSQ]	Time [51]
17. Ease of performing task (assessing risk in the organisation) (PSQ) [PSQ]	Ease of use [62]
18. Effort to perform task (assessing risk in the organisation) (PSQ) [PSQ]	Effort [47]
19. How many analysts have performed the task (participated in the risk assessment)? (SA)	Number of analysts [40]
20. Approximately, what was the total time devoted to using the method by all analysts (the sum of the times of individual analysts)? (enables calculating the average time for one analyst) (SA)	Time [51]

Table 9: Questionnaire for the evaluation of the method's applicability, *Part 4: Strengths and weaknesses of the method*. Questions are mapped to the related applicability concepts. In round brackets, types of questions are denoted: only – LA – longer answer question were used in this part of the questionnaire. The question was adapted from the SUMI standardised questionnaire (indicated in square brackets).

Strengths and weaknesses of the method	
21. In your opinion, what is the greatest strength of the method and why? (LA) [SUMI]	Applicability (general)
22. In your opinion, what requires improvement and why? (LA) [SUMI]	Applicability (general)

Table 10: Supplementary questions for the evaluation of the applicability of a risk assessment method. The questions are mapped to the related applicability concepts. In round brackets, types of questions are denoted: 10PS – 10-point linear scale, SA – short answer, LA – longer answer.

Completeness	
S01. How many risks have you identified with the method? (SA)	Completeness [53]
S02. In your opinion, the risks identified by the method, constitute which part of all possible risks to the organisation? (10PS)	Completeness [53]
S03. How many information assets have been identified with the method? (SA)	Completeness [53]
S04. How many threats has the list of general threats prepared with the method? (SA)	Completeness [53]
S05. How many source lists did you use to build your proprietary (own) list of general threats? (SA)	Completeness [53]
General information	
S06. Approximately, how many users take advantage of the information system for which the risk assessment has been performed? (SA)	Knowledge of the system [52]
S07. How many subnetworks are distinguished in the information system for which the risk assessment has been performed? (SA)	Knowledge of the system [52]
S08. Approximately, how many computers (desktop and mobile) has the information system for which the risk assessment has been performed? (SA)	Knowledge of the system [52]
S09. How many specialised computer devices has the information system for which the risk assessment has been performed? (LA)	Knowledge of the system [52]
S10. Indicate other characteristics of the information system for which the risk assessment has been made. (LA)	Knowledge of the system [52]

the assets identified in the first step and analysed with respect to potential attack vectors. As a result, the list of *dedicated* threats which contains the threats that are specific to the particular organisation, its assets and context is created. For these threats, probabilities of their realisation are evaluated based on expert knowledge. Similarly to impacts, the probabilities are expressed qualitatively in the form of probability levels (e.g. low, moderate, high). In the fourth stage, the impacts and probabilities are referred to each other to obtain risk values. Finally, the risks are ordered according to the descending risk level.

6.2. Results

The evaluation survey, conducted in an online form, provided remarkable insights into the current applicability of the method and the directions of potential improvements. In this section, the survey results that exhibit a more universal character are presented.

Questions 1–9 were dedicated to evaluating the method's completeness, simplicity, effectiveness, accuracy and the satisfaction of use (see Table 6). The equal character of all the questions in the group (5-grade-Likert-scale) enabled the analysis of potential relationships between the usability characteristics. Table 11 presents Spearman correlation coefficients calculated for the 42-units sample together with the indicators of significance (based on the Student's t-test). Among 36 coefficients located below the main diagonal of the matrix, 15 reach 0,4 and higher absolute value, which indicates a moderate correlation between variables. There is a strong indication of a connection between satisfaction and accuracy as well as satisfaction and completeness – three coefficients for each of the pairs evidence the relationship. Two coefficients point to the link between satisfaction and simplicity. In addition, satisfaction tends to be visibly related to effectiveness (ρ=0,62) and weaker than that to accuracy (ρ=0,4). Also, a link between accuracy and completeness can be traced (ρ=0,4). A part of the significant correlation between the variables is caused by their connection to the same applicability factor, for instance, the highest correlation i.e. ρ=0,69 is between responses to questions 8 and 9 – both referring to satisfaction. Similarly, responses to questions 4 and 5 (simplicity) tend to be correlated.

Questions 10 and 11 were devoted to the relationship between the method's application time and the learning time. Based on the sample, no significant correlation could be identified even with the exclusion of extreme values (23 and 22). The calculated Pearson correlation coefficient was 0,18, while the null hypothesis was accepted based on the Student's t-test, both for 0,01 and 0,05 significance levels (two-tailed). The reported times for learning and applying the method are presented in Figure 8.

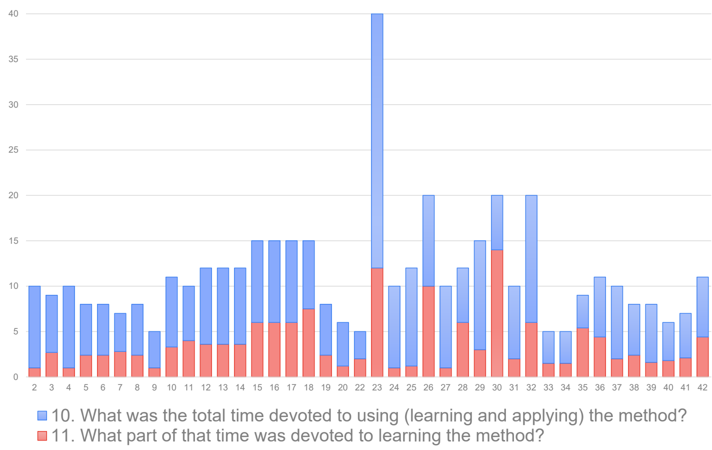

Figure 8: Responses to questions 10 and 11 – Method's learning and applying time.

Interesting results regard the preferred type of support to

Table 11: Spearman correlation matrix for variables associated with questions 1–9.

	1	2	3	4	5	6	7	8	9
1	1								
2	0,62[a]	1							
3	0,54[a]	0,40[a]	1						
4	-0,03[c]	-0,13[c]	-0,04[c]	1					
5	-0,21[c]	-0,31[b]	-0,21[c]	0,59[a]	1				
6	0,33[b]	0,26[c]	0,13[c]	-0,40[a]	-0,35[b]	1			
7	0,46[a]	0,32[b]	0,39[b]	-0,22[c]	-0,27[c]	0,27[c]	1		
8	0,46[a]	0,56[a]	0,35[b]	-0,28[c]	-0,43[a]	0,43[a]	0,43[a]	1	
9	0,62[a]	0,54[a]	0,32[b]	-0,28[c]	-0,36[b]	0,44[a]	0,35[b]	0,69[a]	1

[a] Correlation is significant at the 0,01 level (two-tailed).
[b] Correlation is significant at the 0,05 level (two-tailed).
[c] Correlation is non-significant.

receive when learning the method (question 14). The findings are presented in Table 12. It becomes evident that a practical workshop is the most appealing way of getting familiar with the solution, depicted by more than half of responders (24). As the second option, individual practice with an expert was selected (14 responders). Both options emphasise practical interactions during learning. Less interactive learning forms such as a textbook or a lecture were indicated at a significantly lower ratio (around 10%). However, responders' comments revealed that textbooks or handy manuals could be valuable auxiliary materials that enable individual studying in a convenient location and time.

Table 12: Preferred type of support to receive while learning the method (question 14). Responders could indicate multiple support options.

Type of support	Number of responders*
Practical workshop	24
Individual practice with an expert	14
Textbook	5
Lecture	4
Examples	3
List with all important general threats	2
Asking someone knowledgeable	1
Handy manual	1
It is not hard to learn at all	1
Tutorial video	1

* Some responders indicated several types of support at once.

Figures 9 – 11 are provided for a reference to show the actual level of characteristics related to the complexity and usability of the method, as perceived by the responders. More than half of them consider the method as straightforward in applying and almost 30% would envisage only minor improvements. As far as the time to complete the risk assessment with the method is concerned, 40% of users found it acceptable, while 45% would expect some minor or moderate improvements. The situation is quite similar in regard to the effort required to apply the method. Although these results are relatively positive, they indicate a space for further developments. This reverberates with the observations described earlier.

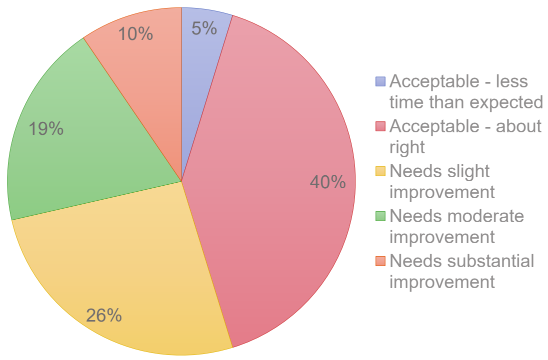

Figure 9: Responses to the question 16 – Time to complete task.

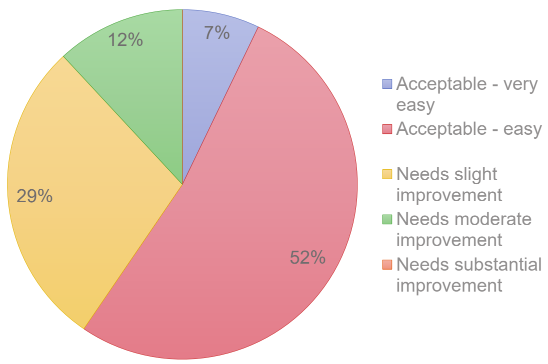

Figure 10: Responses to the question 17 – Ease of performing task.

7. Conclusions

Aiming at supporting the scientific community in the development of methods that will be applied in operational contexts (such as enterprises or infrastructures) and that will meet broader adoption, this study discusses the notion of applicability i.e. the quality of being applicable or suitability to be im-

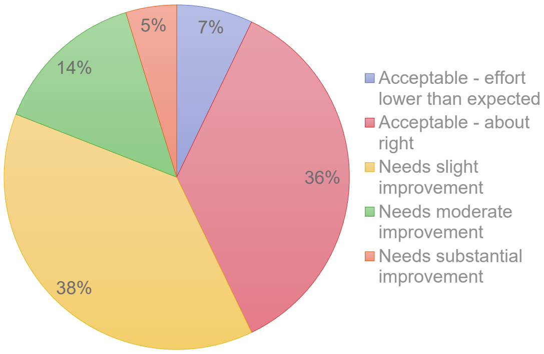

Figure 11: Responses to the question 18 – Effort to perform task.

plemented. Based on an operationalisation process three fundamental constituents of applicability have been identified, namely the complexity, usability and acceptance. Then, 31 determinants associated with these constructs were elicited during a systematic literature review and a taxonomy that consolidates the results was proposed. Additionally, 15 quantitative and 19 qualitative applicability metrics were introduced to enable evaluations of methods' qualities as far as their suitability to be used in operational contexts is concerned. To obtain even a richer view, quantitative metrics can be converted into qualitative ones by formulating questions on users' opinion or impression on the experience related to the given factor.

To support practical evaluations of methods' applicability, a dedicated questionnaire consisting of 22 questions of six different types was designed. To achieve content validity of the instrument, its development initiated with a recursive process, where metrics and concepts from the taxonomy were referred to eight standardised questionnaires associated with the usability domain. As a result, more than a third of the questionnaire consists of questions from the standardised questionnaires. The remaining ones were derived directly from metrics or defined conforming to the convention of the standardised questionnaires. The results of preliminary calculations related to the test's internal reliability (Cronbachs α coefficients) at the level of 0.7 can be a promising indicator of internal consistency. However, further validation needs to be carried on for which a separate study is envisaged.

The taxonomy and metrics were applied to evaluate a cybersecurity risk assessment method. The applicability questionnaire was tailored to the field which included extending it with several supplementary questions. It was then shared online among 42 participants who had earlier experiences with learning and applying the risk assessment method to real contexts. The survey provided valuable insights into the method's applicability. In addition, several observations have a more universal character and can be taken into consideration during developments of other solutions. They concern users' preferences regarding the support obtained during learning a method as well as relations between selected applicability factors. For instance, users indicated as favourite practical and interactive methods of learning how to use a solution, such as workshops with practical exercises or individual practice with experts. Textbooks and manuals, on the other hand, could constitute auxiliary support that enables convenient individual studying. As far as applicability factors are concerned, there is a visible connection between satisfaction from using a method and the method's accuracy. Similarly, the satisfaction is associated with method's completeness, simplicity and effectiveness. Advisably, these findings should be taken into consideration when designing a new method that aims at being widely adopted. Also, they can be helpful in a posteriori analyses, when assessing new proposals, for instance, during project evaluations associated with the distribution of funding. Regarding the further research on the methods' applicability, it will be primarily focused on the comprehensive validation of the questionnaire. The analysis shall comprise larger samples and additional validity, but also reliability tests. Also, a study where quantitative data on the number of real applications of a method will be referred to the results obtained with the questionnaire is planned to be conducted.

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