Metrics for Performance Improvement in Organisations Using Scrum, ITIL and CMMI

[1,2]SUSSY BAYONA-ORÉ, [2]MARCOS HOSTOS
[1]Universidad Autónoma del Perú, Lima, PERÚ
[2]Universidad Nacional Mayor de San Marcos, Lima, PERÚ

Abstract: It is very important to understand the metrics that are applied within IT processes in today's industry, why they are important, and in what types of companies they are used. This article presents the results of a systematic literature review of some of the most widely used metrics exposed in the literature, referring to Scrum, ITIL and CMMi practices. The objective is to determine the scientific progress in this field and to identify the candidate metrics that can be used later in a metrics integration model, designed to help monitor IT services to improving the performance of organisations that use Scrum, CMMi and ITIL. The exploratory search found 1,196 articles, of which 198 were reviewed, from which 31 were finally chosen. From these, a total of 297 metrics were identified, of which 112 (38%) are for Scrum, 98 metrics (33%) are for ITIL, and 87 (29%) are for CMMi. Most of these metrics are used in European companies.

Keywords: ITIL; Scrum; CMMI; Metrics; Measurement.

Received: May 22, 2021. Revised: July 5, 2022. Accepted: August 7, 2022. Published: September 14, 2022.

1. Introduction

We live in a time of great technological advances in hardware and processing power, of large amounts of raw data and new concepts, all under an industrial framework of brand competition and the appetite of native technological consumers. Fitzgerald [1] calls this scenario the "Software Crisis 2.0", characterised by volumes of data to be processed and technological changes that outdate professionals and make processes and methodologies expire.

In the midst of technological progress and competition to offer products and services to meet the demands of the consumer, the need arises to measure as a vital activity required to survive. Mohsen et al. [2] asserts that software metrics are a standard for determining process maturity and required effort.

However, not all companies place importance on the use of metrics. Kettunen et al. [3] shows the results of a survey of 118 respondents, where 41% of them answered that their company does not follow any particular metrics. Gacenga and Cater-Steel [4] complement this by indicating that IT areas give little importance to discussing whether the metrics in place are appropriate.

Therefore, it is necessary to project metrics that are useful and facilitate improving the performance of companies. The scientific literature presents several metrics studies, but only certain studies are focused on Scrum, CMMi and ITIL methodologies and frameworks. It is necessary for any metrics to be developed to have a supporting framework or methodology and that they have been tested in companies since, in a second phase of this work, a metrics integration model will be built. This study is the first part of a proposed model for the integration of Scrum, CMMi and ITIL metrics, which aims to achieve performance improvements in companies that use these practices.

2. Theoretical Framework

The concern for having metrics for various activities is linked to the advancement of humanity. Sydenham [5] considers that civilisation is a direct consequence of the ability to measure, and that measurement is necessary to characterise the universe. In the 1960s and 1970s, metrics focused "on product evaluation, and in the 1980s and 1990s on process evaluation and quality initiatives" [6]. Gradually, the concept of productivity was replaced by the concept of performance.

2.1 Metrics

A metric "is a quantitative measure of the degree to which a system, component or process possesses a given attribute" [7]. Kaner and Bond [8] argue that "measurement is the empirical and objective assignment of numbers, according to a rule derived from a model or theory, to attributes of objects or events with the intention of describing them". Referring to software, a metric is "a standard for measuring the degree to which a software system and process possess some property" [2]. Metrics help track the development of teams and their progress.

2.2 SCRUM

Scrum is a framework used to develop software products. The development process is divided into work cycles, each work cycle is called a sprint, and a sprint has a duration of 2 to 4 weeks. The first activity is determining the requirements to be implemented. The list of requirements is called Product Backlog. The items selected from Backlog during the sprint, cannot change. Their progress is checked and adjusted to complete the work and, at end of the sprint, the results are reviewed [9].

In total, the practice develops 19 processes that are grouped into five phases, each of which describes each process in detail, including inputs, tools and associated outputs [10]. The list of processes contemplated are as follows:

- Phase I. Initiation, which includes Create project vision, Identify Scrum Master and project stakeholders or partners and Scrum Team Formation, develop epic(s), Create prioritized product to-do list and Perform release plan
- Phase II. Planning and Estimation which include the processes Develop User Stories, Approve, Estimate and Assign User Stories, Task Elaboration, Estimate Tasks, and the Develop Sprint Pending List,
- Phase III. Implementation which includes the processes, Conduct Daily Standup, Create Deliverables and Maintain Prioritized Product Backlog,
- Phase IV. Review and Retrospect which include the processes Convene Scrum of Scrums, Sprint Demonstration and Validation, and the Sprint Retrospect, and
- Phase V. Launch which include the Submit Deliverables and Project Retrospective processes.

According to Sharma and Hasteer [11] and Zaouali and Ghannouchi [12], Scrum is the most widely used and most useful agile methodology today, both in research and in industry. However, Mauro and Messina [13] state that Scrum has yet to evolve in terms of metrics, indicating that although "Agile Scrum has been around for over a decade now, there are many successful implementation stories from the Italian Army experience that clearly show there is more conceptual work to be done."

3.3 CMMI

The SEI [14] defines the CMMI Suite as a set of integrated products to support process and product improvement, covering the entire life cycle. CMMi Product Suite has three models: Acquisition (CMMi-ACQ), Services (CMMi-SVC) and Development (CMMi-DEV).

CMMi introduces the concept of maturity levels with the purpose of finding a better way for an organisation to improve their processes. Khraiwesh [15] states that to ensure the survival of the organisation and develop an effective strategy, it is important to adopt a CMMI model, while Amer et al. [16] argue that "CMMI should be used to address aspects of software quality and maturity". CMMI establishes a process area related to metrics. When deploying software processes using CMMI, there must be a repository for metrics [17]. For project management, CMMI is based on the metrics established by PSP and TSP [18].

3.4 ITIL

IT Infrastructure Library (ITIL) is a set of recommendations with descriptions and instructions for the deployment and quality management of information technology-based services. It provides a set of IT practices with tasks, checklists, procedures, processes, activities, roles, the technology associated with change, critical success factors, risks and responsibilities, all of which can be adapted for any IT organisation [19]. With respect to its metrics, ITIL does not define a strategy or sequence for implementing the processes [20].

3. Systematic Literature Review

In order to make a good choice of metrics in companies that use Scrum, CMMi and ITIL practices, we need to make an exploratory study verifying what types of metrics are being used and in what types of companies they are being applied. To determine the main metrics related to Scrum, CMMi e, and ITIL, the method proposed by Kitchenham [21] to conduct a systematic literature review (SLR) is used. This method has three phases, namely (1) Planning, (2) Conducting, and (3) Reporting (see Fig. 1).

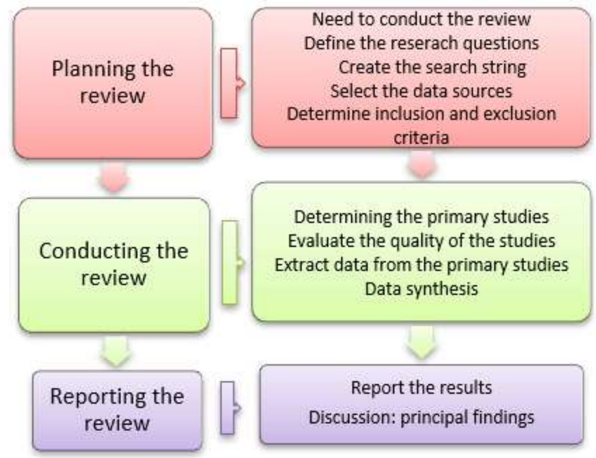

Fig. 1 –Phases of Systematic review

3.1 Planning the review

One of the most important documents in this first phase is the elaboration of the review protocol, a document that will be used to conduct the review. The protocol contains the research questions formulated by [22]. The search string is defined by the keywords used in the research questions. The data sources are identified, and the inclusion and exclusion criteria are determined.

1) Need to conduct the review. Build a catalogue of metrics oriented to improving the performance of production services of a financial company. For this purpose, we need to know the metrics used in Scrum, CMMi and ITIL processes, taking into consideration (1) the research focus: Scrum, CMMi and ITIL metrics, and (2) context: Scrum, CMMi and ITIL practices.

2) Define the research questions. To identify previous scientific articles related to the research topic, a SLR was conducted using the following research question:

What kind of metrics have been used, and in which types *of companies have Scrum, CMMi and ITIL practices been used?*

3) *Create the search string.* The keywords used for the advanced search are:

(metric OR indicator) AND (cmmi OR itil OR scrum)

4) *Select data sources*. The search string was applied to a set of digital libraries that were selected as sources, such as IEEE Xplore, IET Digital Library, Scopus, IEEE Computer Society Digital Library, Web of Science, and Springer Link.

5) *Determine inclusion and exclusion criteria*: The inclusion criteria (IC) and exclusion criteria (EC) were defined to select the studies. The following inclusion criteria were defined:

- IC1: Include articles from 2016 to 2022.
- IC2: Include articles related to CMMi, CMMi-DEV, CMMi-SVC, ITIL and Scrum metrics.
- IC3: Articles must include metrics for CMMi, CMMi-DEV, CMMi-SVC, ITIL and Scrum metrics.

The following exclusion criteria were defined (EC):

- EC1: Studies for which the full content is unavailable.
- EC2: Duplicated studies.
- EC3: Studies not related to technology, projects and processes, as they are considered outside the required range of analysis.
- EC4: Studies that have not used companies as validation or use cases.

3.2 Conduct the Review

In this phase, the primary studies are identified, the quality of these studies is determined, and the information necessary for the research is extracted.

1) *Determining the primary studies*. In the initial search, after removing duplicates and checking that the title and abstract are appropriate, 198 articles were obtained, and we were finally left with 31 articles after examining the content of each study. Table I shows the articles distribution.

TABLE I. PRIMARY STUDIES

Source	Articles Distribution		
	Articles found	**Candidate Articles**	**Primary Articles**
IEEE Computer Society	340	49	5
Scopus	173	89	13
Web of Science	577	23	3
IEEE Xplore	55	23	6
IET Digital Library	30	10	2
Springer Link	21	4	2
Total	1196	198	31

2) *Evaluate the quality of the studies*: The primary studies were evaluated and the quality of the studies was assessed. Table II presents the list of the primary studies as a result of the SLR.

3) *Extract data from the primary studies:* Relevant information from each of the studies was consolidated into spreadsheets recording the information related to this study, metrics used, indicator, description of metric, practices, framework/model/methodology, country, case study, and organisation type.

4. Results

4.1 Distribution of Primary Articles

A total of 31 studies were selected as a result of the SLR, of which 20 (64%) include Scrum metrics; seven articles (23%) cover ITIL; and there are four CMMi articles (13%). The distribution of primary studies is shown in Fig. 2. The fact that almost two thirds of the total number of studies collected focus on Scrum, while ITIL and CMMi share the remaining third, seems to support Sharma and Hasteer [11] and Zaouali and Ghannouchi [12] who state that Scrum is the most used and the most useful agile framework currently available, both in research and in the industry.

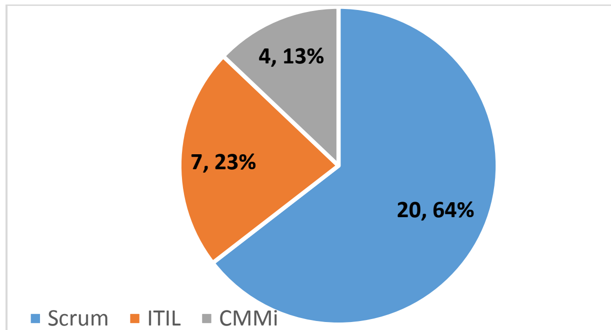

Fig. 2 - Distribution of primary studies related to CMMi, Scrum and ITIL

4.2 Distribution of Primary Items according to Use Case Company or Study Application Site

Within the studies considered, the physical locations of the companies where the case studies were carried out can be seen in Fig. 3. Most of the organisations considered were from the European continent (11 studies), followed by American companies, including South and Central America (8 studies) and multinationals (5 studies). Those considered as several companies are companies delocalized between several countries, with headquarters in Europe, America and Asia (see Fig. 3).

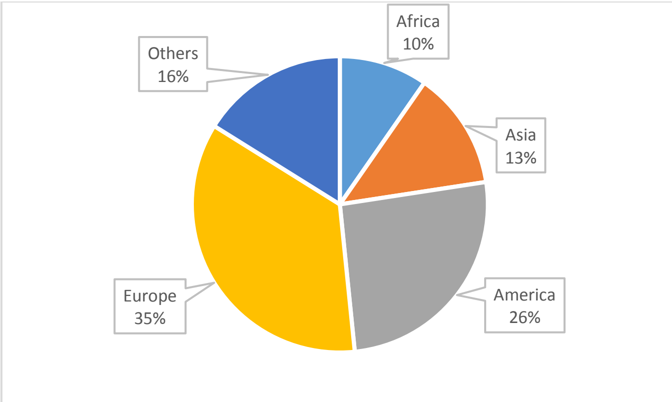

Fig.3 - Location of companies referenced in the studies

As for the sectors in which the companies operate, they were distributed into six types, as shown in Fig. 4.

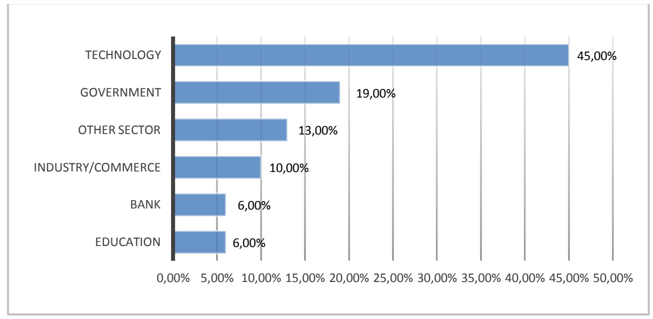

Fig. 4 Sectors to which the companies studied belong

Figure 4 shows that the studies are predominantly in technology companies (14 studies, or 45%), followed by Government and Public with 6 studies (19%) of the total considered. In the category of various sectors are grouped those multi-company studies, mostly of the professional survey type. Table II shows the list of companies according to the case studies carried out (column Country).

TABLE II. COMPANIES REFERENCED IN STUDIES

N	Author	Year	Practice	Case study	Country
1	[23]	2021	Scrum	Enterprise solution team of an anonymous company.	Sudan
2	[24]	2021	ITIL	University, national with 24,000 students.	Bulgaria
3	[25]	2021	ITIL	35 ITIL process executives from telecommunications, IT and the banking industry.	Iran
4	[26]	2021	Scrum	Agile development teams from 14 countries, most of them from Poland.	Other
5	[27]	2020	ITIL	IT Department in Public Electoral Institution.	Mexico
6	[28]	2020	CMMi	Software company with nearly 100,000 employees, and CMMi Level 5.	Other
7	[29]	2020	Scrum	IT services provider with headquarters in more than 20 countries and 38,000 employees.	Other
8	[30]	2020	Scrum	Defense Industries Research and Development Institute.	Turkey
9	[15]	2020	CMMi	University, 300 questionnaires answered by university employees.	Jordan
10	[31]	2019	Scrum	Public company with approximately 200 employees.	Brazil
11	[32]	2019	Scrum	Financial company.	Brazil
12	[33]	2019	Scrum	Private organisation that administers public funds for the provision of water, sewage, electricity and lighting services.	Costa Rica
13	[3]	2019	Scrum	115 respondents, from the IT, financial and retail sectors.	Finland
14	[34]	2019	Scrum	Several state entities with agile projects.	Brazil
15	[35]	2018	Scrum	25 software projects located in Chaco, Corrientes and Misiones.	Argentina
16	[36]	2018	CMMI	Company with offices in Istanbul and Amsterdam, developing software solutions.	Turkey
17	[37]	2018	Scrum	9 projects in 9 different companies.	India
18	[38]	2018	Scrum	IT organisation of digital operators with more than 60 agile teams.	Turkey
19	[39]	2018	Scrum	Interviews with 14 individuals from different organisations in multiple sectors, sizes and countries, most were large, predominantly private sector organisations.	Other
20	[40]	2018	Scrum	Institute oriented to research and development that offer e-government software solutions. This institute has 150 employees, 60 of whom are software engineers.	Turkey
21	[41]	2017	ITIL	IT operations area in SMEs.	Morocco
22	[42]	2017	Scrum	20 projects by 14 industrial contractors for the U.S. Department of Defense.	USA
23	[43]	2017	ITIL	20 engineers from an industrial company's technical staff, belonging to four plants, 10 external support engineers and 5 projects.	Ecuador
24	[44]	2017	ITIL	Company in the telecommunications business, providing data services.	Indonesia
25	[45]	2017	Scrum	Insurance company with end-users in several countries.	Other
26	[46]	2016	CMMi	Company that develops software for the defense industry.	Turkey
27	[47]	2016	ITIL	3 private and public host environments with 29 customers (enterprises) and 11,430 servers analysed.	Germany
28	[48]	2016	Scrum	Company with software equipment distributed between Germany, India and the USA.	Other
29	[49]	2016	Scrum	Medium-sized software development organisation.	Egypt
30	[50]	2016	Scrum	Telecommunications company with an offshore scenario and delivery partnership with provider.	United Kingdom
31	[51]	2016	Scrum	Provider of marketing operations management solutions for large international clients.	Denmark

4.3 SCRUM

Within the review of new developments proposed in the studies is the creation of metrics based on the evidence-based management (EBM) approach proposed by Shirokova et al. [29], conducted in a global company with a presence in more than 20 countries. The authors considered using SAFE (Scale Agile Framework) and achieving transformation success with a system of quantitative and qualitative indicators based on factors such as value, time to market and quality. Tekin et al. [30] studied multi-criteria decision making metrics in a research and development company in the defense industry. The authors perform a systematic selection using expert criteria combined with inclusion of parameters such as robustness, simplicity and cost effectiveness, and refining the choice using the Analytic Hierarchy Process (AHP) method. Velocity Chart, Burndown Chart, and Burnup Chart are the most used metrics by the members of this study group.

More focused on the issue of costs is the study by Chavarria and Madriz [33] who propose a technique for the estimation of return on investment (ROI), applying it in a private organisation that manages public funds. Rosa et al. [42], meanwhile, conducts a study in the US Department of Defense, based on sampling and a questionnaire with IT professionals, analysing size, cost factors, functional requirements and effort, with the aim of improving cost estimations.

Bufon and Leal [32] identify waste indicators such as the number of bottlenecks, work in progress, delays, defects, extras and unfinished work. Regarding metrics to evaluate the agile culture, Gadelsied et al. [23] proposed a model called VGQM (value, goal, question and metric), an extension of the GQM methodology, placing the Scrum values as indicators of core values to be measured and, from this, they focus GQM to establish the necessary indicators, obtaining results that allowed them to evaluate agile culture values.

Kettunen et al. [3] analyse the results of a survey conducted in the IT, financial and retail sectors, investigating agile development in organisations. They conclude that the metrics of cycle time, value, defects and release cycle are the most used. Kovags et al. [34] identify metrics to measure effort in software development using agile methodology, through the review of development contracts in several public administration entities. They conclude that function points remain the most used metric due to their objectivity with respect to functional requirements, in addition to the Service Technical Unit (STU) metric, both of which are present in most contracts.

Arumugam et al. [37] study performance indicators of agile team members through the survey method in nine different companies developing global software, based on four metrics, namely team member velocity, escaped defects, deliverables and effort, which collectively show achievements and detect early warnings that can help Project Managers to manage and activate correction in the project course.

Within the group of studies focused on improving Scrum management is the work of Carneiro et al. [31], who show the use of Scrum in the management of routines, presenting seven indicators to measure their performance. Ertaban et al. [38] propose and test a performance metrics model in the corporate environment of digital operators and develops 12 metrics based on Scrum agile principles aiming to help their agile development teams.

Erdogan et al. [40] performs a statistical analysis in an e-government research institute and concludes that the "statistics of Correlation between history point and Actual effort and Relative estimation" consistency are suitable for team estimation; the statistics of "Actual team effort on product", "Team velocity", "Actual effort for a history point", "Innovation rate" and "Velocity versus unplanned effort rate" are useful for monitoring and increasing team productivity.

Grimaldi et al. [50] applies metrics in an implementation of the SAFe3.0 framework with Scrum teams, seeking to show how a large offshored company and an external provider can work effectively. The authors find eight metrics to quantify the adoption of the applied model and conclude that the introduction of the framework significantly improves the process, in addition to generating cost savings of 8% during the period of observation.

Stettina and Schoemaker [39], based on interviews with 10 large organisations, identify five types of metrics: performance, quality, progress, status and contextual. The results show three domains of knowledge, artifact generation and reporting metrics, identifying and improving the understanding of reporting requirements through new concepts.

In requirements management, Pinto et al. [35] validate their quality in 25 software projects, for which they make use of the AQF (Agile Quality Framework), composed of the QuAM (Agile Quality Model), which contains metrics, attributes, and criteria. This study focuses on the fact that project level quality is not only a numerical value, but it depends on the context in which the process is developed. The results show a considerable reduction in production times, an improvement in communication, and the number of user stories refused by the client are reduced.

Tudjarova et al. [45] conducted a study related to the testing process in an IT company and the software testing metrics across different development methodologies, in order to understand how they influence software quality.

Anwar et al. [49] works on agile adoption in a software company, with the goal of being agile and not losing the CMMi maturity level achieved. For this, they use four metrics related to the reduction of development cost: Testing overhead, Rework, Leaking-defects rate and Customer Satisfaction.

Gupta et al. [48] describes a case study on agile testing adoption in a company environment offshored between Germany, India and the USA, measuring testing effectiveness across 13 metrics. The results maximised the impact of testing on product success, helping developers to collaborate better within teams.

Finally, Marek et al. [26] investigates the impact on agile development teams due to the Covid-19 pandemic by verifying the tools and metrics used. For this purpose, they conduct a global survey of different software engineering teams from 14 countries. The most frequently used metrics were Success Rate, Quality, Velocity, Work in Progress, and Delivered Value.

Table III presents the main metrics used in the Scrum studies.

TABLE III. METRICS USED IN SELECTED SCRUM STUDIES

Indicator	Use	Objetive	Author
LdTime = Tdel - Tdev	Calculation of the task delivery time by subtracting the development time.	Scrum culture evaluation	[23]
Satisfaction	Evaluate customer satisfaction by measuring the time it takes for the team to resolve a customer request.		
SDR=(nuf /tnf)∗ 100%	Evaluate the degree to which teams are focused on the work by measuring the number of features discovered at the end of the product iteration.		
Get the customers feedback.	Ability of organisations to obtain feedback from customers.		
Cross rate= (Croimp/ TotTask) ∗ 100%	Level within the team by calculating the number of cross-deployments that occurred by overstepping without taking into account the permission of other teammates.		
CourC = (RejUn / TotUn) ∗ 100%	Measures the level of commitment to the customer by rejecting unnecessary requests that may hinder the work process.		
CourT= ActiveMember/to talMember)∗100%	Manager's commitment to eliminate inactive team members.		
Velocity, Quality, Work in progress, goal success rate, Value delivered, Productivity, Sustainability, Delivered rate, Lead time, Focus factor, Cycle time, Throughput, Work ítem and Cost of delay	Metrics most used by remote work teams during Covid-19	Metrics used for agile team management due to the pandemic	[26]
Daily resolved defects per team member, Focus Factor, Vanity Metrics, Skills gained and shared with the team and Weekly work hours reporting instead of monthly reporting	New metrics used for Covid-19		
Revenue per Employee	Key competitive indicator within an industry.	Value Area: Current Value	[29]
Product Cost Ratio	Total expenses and costs including operating costs compared to revenues		
Employee Satisfaction	To measure employee engagement (energy and enthusiasm) using sentiment analysis		
Customer Satisfaction	To measure customer engagement (product happiness) using sentiment analysis		
Release Frequency	# of launches per time period	Value Area: Time to market	
Cycle Time	Time between the start of work and the point at which it is launched		
Lead Time	Time between the idea proposed and the customer benefiting from it		
# of defects	# of defects found (by cycle).	Value Area: Quality	
# of incidents	# of complaints collected from customers and users about software quality after release.		
# of repeated defects	# of defects repeating from one cycle to the other		
Punctually of daily meeting (DM)	Effort of the IT department to measure its performance through Scrum practices.	Measuring the performance of Scrum practices	[31]
Adherence to planning (%)			
Points accepted by the PO (%)			
Burn-ups inserted (%)			
Sprint Speed			
Average of people in each sprint			
Points achieved per person			
Retorno de la inversión (ROI)	Measuring project costs and return on investment	Estimate costs at the end of each sprint	[33]
TIR (Taza interna de retorno)			
VAN (Valor actual neto)			
# of bottlenecks (NB)	# of bottlenecks considering the delivery time of a requirement	Indicators for waste control in projects	[32]
Work in progress (WIP)	WIP adjusted to quantify all requirements that deviate from the value stream		
# of accumulated items (NAI)	# of cumulative requirement items for each contributor in each development phase		
Cycle time, Lead time (features, epics, issues), release cycle, Defects, Outcomes, releases, Velocity, Automation (test, release), Predictability, Employee experience, and customer experience	Most used metrics by companies	Metrics used in the company	[3]
Escaped defects	Measuring defects in the delivered product.	Individual performance of team members	[37]
Team member velocity	Completeness of tasks according to commitments.		
Deliverables	Effectiveness of delivery within the specified time.		
Effort	Ratio of efforts devoted to correction vs. efforts to develop it.		
Velocity	Related to production.	Agile performance indicators	[38]
Lead Time and Cycle Time			
Distribution of Waste (bottleneck waste)			
Number of Defects	Related to quality.		
Defect Density			
# of Active Customers	Customer satisfaction.		
Coefficient of Determination	Shows how much variation in the dependent variable is explained by the regression equation.	Estimate agile software cost development effort through analysis of product size, staffing, and domain.	[42]
Coefficient of Variation	% expression of the standard error compared to the mean of the dependent variable.		
Variance Inflation Factor	Method used to indicate whether multicollinearity is present in a multiple regression analysis.		
Standard Error	The standard error of the estimate is a measure of the difference between the estimated and observed effort.		
Mean Magnitude of Relative Error (MMRE)	MMRE is defined as the sample mean (M) of the magnitude of the relative error (MME). MME is the absolute value of the difference between the actual and estimated effort divided by the actual effort.		
Testing overhead	Total effort consumed in testing, calculated as a percentage of total effort consumed in code writing.	Reduce the cost of development	[49]
Rework	Total effort consumed in fixing defects, calculated as a percentage of total effort consumed in code writing.		
Rate of leaking-defects	# of found defects that belong to the basic coverage category, calculated as a percentage of the total number of found defects.		
Customer Satisfaction	Average rating for a product given by the customer.		
Delta estimation precision (DEP)	The precision of the estimation.	Quantify the	[50]

Indicator	Use	Objetive	Author
Effectiveness (IE)	Internal effectiveness.	benefit achieved with the adoption of the proposed model	
Efficiency (TE)	Technical efficiency.		
Waste (W)	Cost originated from DEP.		
Impediments (I)	# of hours that do not produce a tangible outcome		
Product Backlog Rating (PBR)	PBR considers the product complexity level (PCL).	Measuring the quality of tests	[51]

4.4 CMMi

In process improvements and control are the studies of Utku and Şahin [36] who define metrics within a CMMi-DEV-based approach to develop a software process diversity model using CMMi v.2. The implementation of the processes increased speed and reduced the number of failures. On process auditing, Agrawal & Chari [28] use the process audit review and control (ARC) effort metric to estimate defects and overall effort in a software project. The data of a total of 49 software projects from a global CMMi Level 5 organisation were used. The results showed higher audit effort in the requirements and project build phases.

Khraiwesh [15] studies Organisational Training (OT) and applied the Goal Question Metrics (GQM) model to seven organisational training objectives in the CMMi framework, obtaining metrics derived from OT practices which he then confirmed by using a questionnaire to test validity and reliability. Cenkler [46] studies the evolution of process and product metrics of an organisation that develops software for the defense industry. The objective was to meet the requirements of CMMi-Development and ISO 9001 certification, for which he defines process and product metrics for the purpose of data collection, analysis and decision making.

With this study, weaknesses were detected such as the useless effort of collecting 52 metrics, the lack of clear business objectives, and it was verified that many metrics did not contribute to the objective. As a result, the metrics evolved to only 39, which brought effectiveness to the process. Table IV shows the metrics identified in the CMMi studies.

TABLE IV. METRICS USED IN SELECTED CMMI STUDIES

Indicator	Use	Objective	Author
Process audit review and control (ARC) effort	Product quality assurance and Process	Providing information on work products and processes.	[28]
Function points	Project size	Project audit review and control	
The software development effort	Includes the effort from requirements gathering, design, coding, testing and acceptance testing		
Software quality	Defect counts delivered to the customer		
Total number of days	Number of failures at the end of the project and speed improvement.	Evaluate failures and speed at the end of the project.	[36]
Number of days' delay			
Planned person days			
Realised person days			
Daily average closed			
Person days			
# of analysis test faults			
# of approved set faults			
# of approved			
Set faults per day			
Earned Value Analysis	Project management	Metrics that evolved as a result of the case study	[36]
Project risk mitigation effectiveness	Risk management		
Performance Satisfaction Score for Subcontractors,	Subcontract management		
Volatility of software requirements	Metrics in the area of product development		
Customer satisfaction score including cost, schedule and STM relations issues	Customer satisfaction metrics		
Proportion of corrective actions for non-compliances assessed as effective.	Quality assurance metrics		
Number of effective training sessions per person	Metrics in the training area		

4.5 ITIL

In relation to metrics to measure performance, Barcelo-Valenzuela and Leal-Pompa [27] present an ITSM methodological adaptation of ITIL, providing indicators and procedures for an IT department to be able to measure its performance. They provide 18 metrics based on service reports and a continuous improvement process and conclude with a case study in an electoral body that saw on 88% improvement in times to service requests.

Fiegler et al. [47] introduce system entropy and operation learning to evaluate the quality of IT service management processes. The expected metrics were confirmed in two out of three real environments. This would benefit the controllability and compliance with SLAs in cloud environments.

Regarding incident management, Nugraha and Legowo [44] evaluate such processes in a telecommunications corporation, obtaining four metrics that allow for reviewing incident management factors, in addition to observations of the processes for improvement purposes.

For the achievement of business objectives, Mitev and Kirilov [24] propose a metrics selection methodology based on a group decision making approach to evaluate their relevance. As a case study, the quality of a university's email service was evaluated through 18 metrics that measured availability, requirements, incidents, changes and capacity.

Bustamante et al. [43] expose metrics from a year of continuous improvement in a study conducted in an industrial plant that needs to adapt IT frameworks, such as PMI-PMBOK, COBIT, NIST and ITIL. Their purpose was to protect companies against disruptions and malicious IT activities. The main results were an alignment to strategic objectives, reduction in incidents, holistic management, and information security control.

Finally, Baradari et al. [25] determine the relationship between knowledge management (KM) and IT Service management (ITSM) to establish a basis for the design of an integrated system, focusing on ITSM processes of configuration, changes, release, incidents and problems, listing a total of 44 metrics, and applying fuzzy cognitive mapping to identify the relationships and key performance indicators of ITSM processes. Table V lists the main ITIL metrics found in the literature.

TABLE V. METRICS USED IN SELECTED ITIL STUDIES

Indicator	Use	Objetive	Author
% of incidents closed by the service desk	Incident management	Evaluate the performance of ITIL processes	[25]
Uptime percentage of the service	Service availability	Evaluation of e-mail service quality	[24]
Count of complete unplanned service outages			
Count of service degradation events			
Average time for completing the service requests	Service request management		
% of service requests completed within the agreed SLA			
% of service requests completed within one shot			
% of complaints			
Average time for starting work on case	Incident management		
Average time for resolution			
% of incidents resolved within the SLA timeframes			
% of incidents completed within one shot			
% of incidents with proper initial assessment			
% of complaints			
% of successful changes	Change management		
# of failed changes			
# of unauthorized changes			
Consumed disc storage per user	Capacity		
Supported user per FTE			
# of services	Service portfolio management	Planning	[27]
# of services	Service catalogue management		
# of unavailability incidents	Service level Management		
# of lack of capacity incidents			
# of preventive measures implemented	Information security management		
# of service requests	Transition planning and support	Transition	
# of changes per service	Change management		
# of non- planned changes per service			
% of deadlines compliance			
% of successful service deployment	Release and deployment management		
# of service or incident requests	Incident management	Evaluation	
# of requests to attend			
# of requests in process			
# of requests completed			
# of requests per type			
% of requests per type			
% of requests per priority			
# of KPI's implemented	Continual improvement process		
Weekly reports	Service reports		
# of incidents, Incident resolution time, Rate of incidents resolved remotely, Rate of incidents resolved within SLA	Incident management	ITIL Key Performance Indicators	[41]
# of problems, Rate of unresolved problems, Problem Resolution Time, Rate of proactive problem solving	Problem management		
Rate of emergency changes, Change accepted rate, Time for change Approval/Rejection, Rate of unsuccessfully realised changes	Change management		
Number of Incidents	Total incidents completed as a control measure	Incident management process metrics	[44]

Indicator	Use	Objetive	Author
Percentage of Trouble handled within target resolution time	Percentage of problems handled within the target response time		
Average duration of trouble tickets by priority	Average duration from creation to closure of trouble tickets of each priority.		
First time restoration	Number of Tickets that FO restores for the first time after opening		
System operation learning	ITIL en cloud con DevOps	Asses the quality of IT service management processes	[47]

5. Conclusions

Having metrics is of vital importance if one wants to measure the progress of processes. This study provides 31 selected papers from different data sources that were reviewed using the systematic review method with the purpose of identify the main metrics used by organisations, public or private, 35% of which were European, that adopted practices related to SCRUM, CMMi or ITIL. As a result, a total of 297 metrics were identified, of which 38% are Scrum (112 metrics), 33% are ITIL (98 metrics) and 29% are CMMi (87 metrics). In terms of sector, there is a clear inclination towards technology-oriented companies (45%), followed by government companies (19%) and diverse sectors (13%). In the case of Scrum, the greatest trend of metrics exposed resides in those used for agile software management purposes (33%, 59 metrics), followed by those used for agile quality management (21%, 38 metrics), and then those metrics used to control costs or delivery value to the customer (17%, 31 metrics). In the case of CMMi, the organisation's training metrics stand out at 75% (65 metrics), followed far behind by project monitoring and control (14%, 12 metrics). Regarding ITIL metrics, the three types of objectives with the highest number of metrics are: Incident management with 29% (31 metrics), change management with 18% (19 metrics) and problem management with 13% (14 metrics).

This research found opportunities for future research on metrics, their usefulness, their impact on the quality of services and products, their benefits and, most importantly, to create a culture of using metrics, especially in public organisations. The results of this study can be used to implement a historical metrics repository for future projects and to follow the best practices of CCMi such as in the measurement and analysis process area. To improve the performance of a private organisation, as future work, a metrics framework based on CMMi, Scrum and ITIL will be developed.

References

[1] Fitzgerald, B. (2018). Software Crisis 2.0. In Software Technology: 10 Years of Innovation in IEEE Computer (pp. 1–16). IEEE. https://doi.org/10.1002/9781119174240.ch1.

[2] Mohsen, W., Aref, M., & ElBahnasy, K. (2017). Software metrics for cooperative scrum based ontology analysis. 2017 2nd International Conference on Knowledge Engineering and Applications (ICKEA), 60–70. https://doi.org/10.1109/ICKEA.2017.8169903

[3] Kettunen, P., Laanti, M., Fagerholm, F., & Mikkonen, T. (2019). Agile in the Era of Digitalization: A Finnish Survey Study. Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 11915 LNCS, 383–398. Scopus. https://doi.org/10.1007/978-3-030-35333-9_28

[4] Gacenga, F., & Cater-steel, A. (2011). Performance Measurement Of IT Service Management: A Case Study Of PERFORMANCE MEASUREMENT OF IT SERVICE MANAGEMENT: A CASE STUDY OF AN AUSTRALIAN.

[5] Sydenham, P. H. (2003). Relationship between measurement, knowledge and advancement. Measurement, 34(1), 3–16. https://doi.org/10.1016/S0263-2241(03)00023-X

[6] Bundschuh, M., & Dekkers, C. (2008). Software Measurement and Metrics: Fundamentals. In The IT Measurement Compendium (pp. 179–206). Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-540-68188-5_7

[7] IEEE (1990). IEEE Standard Glossary of Software Engineering Terminology. IEEE Std 610.12-1990, 1–84. https://doi.org/10.1109/IEEESTD.1990.101064

[8] Kaner, C., & Bond, W. P. (2004). Software Engineering Metrics: What Do They Measure and How Do We Know? Undefined. https://www.semanticscholar.org/paper/Software-Engineering-Metrics%3A-What-Do-They-Measure-Kaner-Bond/7e63e256311e956093f9bea27456bc4e7206325a

[9] Salinas, C. J. T., Escalona, M. J., & Mejías, M. (2012). A Scrum-based Approach to CMMI Maturity Level 2 in Web Development Environments. Proceedings of the 14th International Conference on Information Integration and Web-Based Applications & Services, 282–285. https://doi.org/10.1145/2428736.2428782

[10] Salazar, A. (2016, October 16). Procesos de Scrum. Prozess Group. http://www.prozessgroup.com/procesos-de-scrum/

[11] Sharma, S., & Hasteer, N. (2016). A comprehensive study on state of Scrum development. 2016 International Conference on Computing, Communication and Automation (ICCCA), 867–872. https://doi.org/10.1109/CCAA.2016.7813837

[12] Zaouali, S., & Ghannouchi, S. A. (2020). Quality assessment in scrum software development through Metrics: A conceptualization using concept maps. 161–166. Scopus.

[13] Mauro, V., & Messina, A. (2016). AMINSEP-agile methodology implementation for a new software engineering paradigm definition. A research project proposal. Communications in Computer and Information Science, 422, 27–33. Scopus. https://doi.org/10.1007/978-3-319-27896-4_3

[14] Software Engineering Institute. (2010). CMMI® para Servicios, Versión 1.3.

[15] Khraiwesh, M. (2020). Measures of Organisational Training in the Capability Maturity Model Integration (CMMI). International Journal of Advanced Computer Science and Applications, 11(2), 584–592.

[16] Amer, S. K., Badr, N., & Hamad, A. (2020). Combining CMMI Specific Practices with Scrum Model to Address Shortcomings in Process Maturity. In A. E. Hassanien, A. T. Azar, T. Gaber, R. Bhatnagar, & M. F. Tolba (Eds.), The International Conference on Advanced Machine Learning Technologies and Applications (AMLTA2019) (pp. 898–907). Springer International Publishing. https://doi.org/10.1007/978-3-030-14118-9_88

[17] Sussy, B. L., Antonio, C. M. J., Gonzalo, C., Tomás, S. F., & Angel, S. (2008). Process deployment in a multi-site CMMI level 3 organisation: a case study. In Computer and Information Science (pp. 147-156). Springer, Berlin, Heidelberg

[18] Chavarría, A. E., Oré, S. B., & Pastor, C. (2016). Aseguramiento de la Calidad en el Proceso de Desarrollo de Software utilizando CMMI, TSP y PSP/Quality Assurance in the Software Development Process using CMMI, TSP and PSP. Revista Ibérica de Sistemas e Tecnologias de Informação, (20), 62.

[19] Steinberg, R. A. (2011). ITIL Service Operation (2011 ed. edition). The Stationery Office.

[20] Sánchez, R., & Luis, J. (2021). Model to Optimize the Decision Making on Processes in IT Departments. Mathematics, 9(9), 983. https://doi.org/10.3390/math9090983

[21] Kitchenham, B. (2004). Procedures for Performing Systematic Reviews (Joint Technical Report). Software Engineering Group, Department of Computer Science, Keele University and Empirical Software Engineering National ICT Australia Ltd. https://scholar.google.es/scholar?hl=es&q=procedures+for+performing+systematic+reviews&btnG=&lr=&oq=procedures+for+per

[22] Bayona, S., Calvo-Manzano, J. A., & San Feliu, T. (2013, June). Review of critical success factors related to people in software process improvement. In European Conference on Software Process Improvement (pp. 179-189). Springer, Berlin, Heidelberg.

[23] Gadelsied, A. O., Elhassan, T. M. M., Mohamed, W. M., & Abushama, H. M. (2021). Assessment method for Scrum culture within the Development team. 2020 International Conference on Computer, Control, Electrical, and Electronics Engineering (ICCCEEE), 1–6. https://doi.org/10.1109/ICCCEEE49695.2021.9429608

[24] Mitev, Y., & Kirilov, L. (2021). Group Decision Support for e-Mail Service Optimization through Information Technology Infrastructure Library Framework. 227–230. Scopus. https://doi.org/10.15439/2021F93

[25] Baradari, I., Shoar, M., & Nezafati, N. (2021). Defining the relationship between IT Service management and knowledge management: Towards improved performance. Knowledge Management Research and Practice. Scopus. https://doi.org/10.1080/14778238.2021.1903349

[26] Marek, K., Wińska, E., & Dąbrowski, W. (2021). The State of Agile Software Development Teams During the Covid-19 Pandemic. Lecture Notes in Business Information Processing, 408, 24–39. Scopus. https://doi.org/10.1007/978-3-030-67084-9_2

[27] Barcelo-Valenzuela, M., & Leal-Pompa, C. M. (2020). An ITSM framework adaptation: Case study in an electoral institution. 468–473. Scopus. https://doi.org/10.1109/CDS49703.2020.00098

[28] Agrawal, M., & Chari, K. (2020). Impacts of process audit review and control efforts on software project outcomes. IET Software, 14(3), 293–299. https://doi.org/10.1049/iet-sen.2019.0185

[29] Shirokova, S., Kislova, E., Rostova, O., Shmeleva, A., & Tolstrup, L. (2020). Company efficiency improvement using agile methodologies for managing IT projects. ACM International Conference Proceeding Series. Scopus. https://doi.org/10.1145/3446434.3446465

[30] Tekin, N., Kosa, M., Yilmaz, M., Clarke, P., & Garousi, V. (2020). Visualization, Monitoring and Control Techniques for Use in Scrum Software Development: An Analytic Hierarchy Process Approach. Communications in Computer and Information Science, 1251 CCIS, 45–57. Scopus. https://doi.org/10.1007/978-3-030-56441-4_4

[31] Carneiro, L. B., Silva, A. C. C. L. M., & Alencar, L. H. (2019). Scrum Agile Project Management Methodology Application for Workflow Management: A Case Study. 2019-December, 938–942. Scopus. https://doi.org/10.1109/IEEM.2018.8607356

[32] Bufon, M. T., & Leal, A. G. (2019). Method for identification of waste in the process of software development in agile teams using lean and scrum. Communications in Computer and Information Science, 1027, 466–476. Scopus. https://doi.org/10.1007/978-3-030-21451-7_40

[33] Chavarria, R. C., & Madriz, F. L. (2019). Roi estimation in a scrum project: A case study. 64, 78–87. Scopus. https://doi.org/10.29007/nqq6

[34] Kovags, D., Falchi, F. L., & Rivas, A. R. (2019). Analysis of the utilization of scrum framework effort estimation metrics in federal public administration. ACM International Conference Proceeding Series. Scopus. https://doi.org/10.1145/3364641.3364645

[35] Pinto, N., Tortosa, N., Geat, B. C., Ibáñez, L., & Bollati, V. (2018). Quality Evaluation of Agile Processes: Measurement of Requirements Management Using AQF v2. 15–20. https://doi.org/10.1109/QUATIC.2018.00013

[36] Utku, S., & Şahin, S. (2018). Process diversity in software development: An industrial study. IET Software, 13(4), 260–267. https://doi.org/10.1049/iet-sen.2018.5079

[37] Arumugam, C., Vaidayanthan, S., & Karuppuchamy, H. (2018). Global software development: Key Performance measures of team in a SCRUM based agile environment. Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 10963 LNCS, 672–682. Scopus. https://doi.org/10.1007/978-3-319-95171-3_53

[38] Ertaban, C., Sarikaya, E., & Bagriyanik, S. (2018). Agile performance indicators for team performance evaluation in a corporate environment. Part F147763. Scopus. https://doi.org/10.1145/3234152.3234156

[39] Stettina, C. J., & Schoemaker, L. (2018). Reporting in agile portfolio management: Routines, metrics and artefacts to maintain an effective oversight. Lecture Notes in Business Information Processing, 314, 199–215. Scopus. https://doi.org/10.1007/978-3-319-91602-6_14

[40] Erdogan, O., Pekkaya, M. E., & Goek, H. (2018). More effective sprint retrospective with statistical analysis. Journal of Software-Evolution and Process, 30(5), e1933. https://doi.org/10.1002/smr.1933

[41] Yamami, A. E., Mansouri, K., Qbadou, M., & Illousamen, E. H. (2017). Multi-criteria decision making approach for ITIL processes performance evaluation: Application to a Moroccan SME. 2017 Intelligent Systems and Computer Vision (ISCV), 1–6. https://doi.org/10.1109/ISACV.2017.8054937

[42] Rosa, W., Madachy, R., Clark, B., & Boehm, B. (2017). Early Phase Cost Models for Agile Software Processes in the US DoD. 30–37. https://doi.org/10.1109/ESEM.2017.10

[43] Bustamante, F., Fuertes, W., Diaz, P., & Toulkeridis, T. (2017). Integration of IT frameworks for the management of information security within industrial control systems providing metrics and indicators. Proceedings of the 2017 IEEE 24th International Congress on Electronics, Electrical Engineering and Computing, INTERCON 2017. Scopus. https://doi.org/10.1109/INTERCON.2017.8079672

[44] Nugraha, A. D., & Legowo, N. (2017). Implementation of incident management for data services using ITIL V3 in telecommunication operator company. 2017 International Conference on Applied Computer and Communication Technologies (ComCom), 1–6. https://doi.org/10.1109/COMCOM.2017.8167093

[45] Tudjarova, S., Chorbev, I., & Joksimoski, B. (2017). Software Quality Metrics While Using Different Development Methodologies. Communications in Computer and Information Science, 778, 240–250. Scopus. https://doi.org/10.1007/978-3-319-67597-8_23

[46] Cenkler, Y. (2016). Evolution of Process Product Metrics Based on Information Needs. 2016 10th International Conference on the Quality of Information and Communications Technology (QUATIC), 143–145. https://doi.org/10.1109/QUATIC.2016.036

[47] Fiegler, A., Zwanziger, A., Herden, S., & Dumke, R. R. (2016). Quality Measurement of ITIL Processes in Cloud Systems. 2016 Joint Conference of the International Workshop on Software Measurement and the International Conference on Software Process and Product Measurement (IWSM-MENSURA), 87–94. https://doi.org/10.1109/IWSM-Mensura.2016.022

[48] Gupta, R. K., Manikreddy, P., & GV, A. (2016). Challenges in Adapting Agile Testing in a Legacy Product. 2016 IEEE 11th International Conference on Global Software Engineering (ICGSE), 104–108. https://doi.org/10.1109/ICGSE.2016.21

[49] Anwar, A., Kamel, A. A., & Ahmed, E. (2016). Agile adoption case study, pains, challenges & benefits. 28-29-May-2016, 60–65. Scopus. https://doi.org/10.1145/2944165.2944175

[50] Grimaldi, P., Perrotta, L., Corvello, V., & Verteramo, S. (2016). An agile, measurable and scalable approach to deliver software applications in a large enterprise. International Journal of Agile Systems and Management, 9(4), 326–339. Scopus. https://doi.org/10.1504/IJASM.2016.081561

[51] Kayes, I., Sarker, M., & Chakareski, J. (2016). Product backlog rating: A case study on measuring test quality in scrum. Innovations in Systems and Software Engineering, 12(4), 303–317. Scopus. https://doi.org/10.1007/s11334-016-0271-0