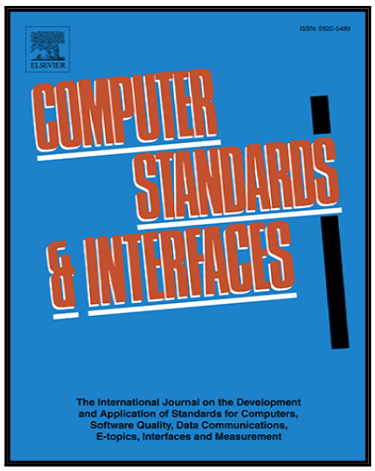

Supporting the Deployment of ISO-based Project Management Processes with Agile Metrics

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Highlights

- Agile mature companies can be also conformant with ISO process reference models.
- Conformance with five ISO/IEC/IEEE 12207 Technical Management processes is analysed.
- Conformance with two ISO/IEC TR 29110-5-1-2 Project Management process activities is analysed.
- Agile approaches propose different metrics for monitoring team performance.
- Agile approaches are not faced with traditional process models.

Supporting the Deployment of ISO-based Project Management Processes with Agile Metrics

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Abstract. Agile approaches are well perceived in software development companies. These approaches are not faced with traditional process models. This research analyses how by defining and monitoring a set of Agile metrics, Agile mature companies can be also conformant with the best practices proposed by the targeted ISO process reference models. Conformance has been identified with five Technical Management processes of the ISO/IEC/IEEE 12207 standard and with two activities of the Project Management process of the ISO/IEC TR 29110-5-1-2 standard. The findings may be of the interest of those Agile settings that need to work according to the process model established in the company.

Keywords: Agile, Metrics, Project Management, Software Process Improvement, ISO/IEC/IEEE 12207, ISO/IEC TR 29110-5-1-2.

1 Introduction

Since the emergence of Agile in the early 1990s, Information Technology (IT) companies have had an increasing interest in applying Agile software development methods. Many settings claim to be Agile or wish to adopt these methods [1]. Implementation of Agile approaches helps software development companies to tailor their services and products, thus providing the ability to adapt to current dynamics in the market [2], [3]. The use of Agile has caused a significant change on how projects are organized and executed [4], [5]. Due to its optimization effect and reduction of overhead, Agile practices can help mature organizations to become more flexible [6], [7]. As a consequence, Agile approaches are well perceived by both management and developers [8], and software development organizations recognize the need for agility in nearly every project they execute [9]. Agile approaches are also appropriate for organizations that develop critical software, as well as for other settings in other critical sectors such as automobile, medical or aerospace, among others. Although this kind of companies need to show conformance to recognized and widely accepted standards such as CMMI or SPICE, they need to be more agile. In any case, it is not incompatible to have a certification according to a maturity model and work following an Agile approach.

Different authors have proposed different models and approaches with measures and indicators to evaluate how Agile is an organization [10]. Sidky's approach is based on a tool able to provide a set of indicators used to measure the agility of a company calculating the amount of agile practices they use [11]. In [12], authors develop a test to evaluate if the agile adoption framework can be used to measure current agility, suggest changes in the agile adoption framework and highlight the issues connected to agility measurement. In [13], Özcan and Demirörs perform a multiple case study in a software organization to evaluate the capabilities of the existing Agile maturity/assessment models based on six criteria. The defined criteria were mainly associated with the study of Maier et al. [14] on the development of organizational maturity grids. In [15] authors investigate how agile teams evolve to maturity. In [16], authors evaluate a wide set of agility assessment tools mainly useful to indicate a level of agility. In [17], the Software Agility Assessment Reference Model (AgilityMod) to assess agility levels of software projects is presented. This model provides guidance in identifying the state of projects with respect to agility, and depicts improvement opportunities in relation with the Agile practices. The meta-model of AgilityMod was defined according to the principles defined in ISO/IEC 15504 Process Assessment Model (PAM) [18]. Agile Maturity Models (AMMs) suggest that agile practices are introduced in a certain order. However, whether the order of agile practice introduction as suggested in the AMMs is relevant in industry has not been evaluated in an empirical study [19].

Some Agile approaches define a set of metrics, such as *flow efficiency*, *lead time* or *cycle time*, that monitor the real progress of the project. These metrics are very useful for the team to identify issues early, to reduce re-work and to determine the most critical tasks to address in new iterations [20], [21]. Moreover, they provide the knowledge needed to improve the planning of new projects, suffer less deviations and, consequently, increase customer satisfaction [22], [23].

In our research, focused on Agile mature companies, experienced in the application of Agile approaches, we analyse how Agile performance metrics can help the successful processes deployment. In order to perform this analysis, we have considered as reference standards the ISO/IEC/IEEE 12207 [24] for software life cycle processes and the ISO/IEC TR 29110-5-1-2 [25] for Very Small Entities (VSEs). In both international standards, in addition to the software development processes, project management processes are also included.

Project management is the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements [26]. Projects are usually organized into phases that are determined by governance and control needs. These phases should follow a logical sequence, with a start and an end, and should use resources to provide deliverables. In order to manage the project efficiently, a set of activities should be performed in each phase. To manage a project throughout its life cycle, different project management processes should be deployed [27]. The project management processes may be grouped into five process groups corresponding to the project life cycle phases: Initiating, Planning, Executing, Monitoring and Controlling, and Closing.

It is well known and accepted that most of the effort needed for the management of a project is devoted to the Planning phase. IT companies, in general, dedicate time and resources to plan the scope of the project, to determine the tasks to be carried out, to elaborate the project schedule, to calculate the budget of the project, to identify the risks

and to establish the mitigation plan, among other planning tasks. However, once the project is in the Execution phase, valuable data for Monitoring and Control are not always collected, neither the necessary re-planning to handle deviations is usually properly formalized. These shortcomings in implementing Monitoring and Control processes give as a result a lack of real data of the project progress and, therefore, do not facilitate the improvement of future predictions. In addition, the knowledge of the company's projects is not real, since it is based on estimates and not on facts.

When working with Agile approaches, and according to the principles of the Agile Manifesto [28], the primary measure of progress is an incremental deliverable that is functional and provides value. Agile life cycles combine both iterative and incremental approaches in order to adapt to high degrees of change and deliver value more often. The team gains early feedback and provides customer visibility, confidence, and control of the product [29]. Monitoring and control activities are usually carried out during the Agile meetings. Scrum proposes four different types of meetings: sprint planning, daily scrum, sprint review and sprint retrospective. These ceremonies can be seen, on the one hand, as review points to monitor and control a proper execution of the project and, on the other hand, to plan new iterations.

The goal of our study is to get to know if an agile mature company also satisfies the guidelines and recommendations of wide-spread international standards for software development. Specifically, if the set of performance metrics, are conformant with the best practices of the related project management processes included in the targeted standards. Then, the research question is *Can Agile metrics support the deployment of the project management processes proposed by the ISO/IEC/IEEE 12207 and the ISO/IEC TR 29110-5-1-2 standards*?

The paper is organized as follows. Section 2 presents the ISO/IEC/IEEE 12207 and the ISO/IEC TR 29110-5-1-2 standards. Section 3 introduces different Agile metrics and discusses their usefulness for project monitoring and control. Section 4 describes how the deployment of the processes for project monitoring and control in the targeted ISO standards can be supported by these Agile metrics. Finally, Section 5 opens discussion about the results and concludes the paper.

2 Overview of targeted ISO standards

This section presents the selected standards for the purpose of this research: ISO/IEC/IEEE 12207 and ISO/IEC TR 29110-5-1-2.

2.1 ISO/IEC/IEEE 12207

ISO/IEC/IEEE 12207 [24] establishes a common framework for software life cycle processes, with well-defined terminology, that can be referenced by the software industry. It contains processes, activities and tasks that are applicable during the acquisition, supply, development, operation, maintenance or disposal of software systems, products, and services. This international standard provides a Process Reference Model (PRM) that groups the activities that can be performed during the life

cycle of a software system into four process groups. These four process groups and the processes included in each group are depicted in Figure 1. ISO/IEC/IEEE 12207 can be used as a reference model to support process assessment as specified in ISO/IEC 33002:2015 [30].

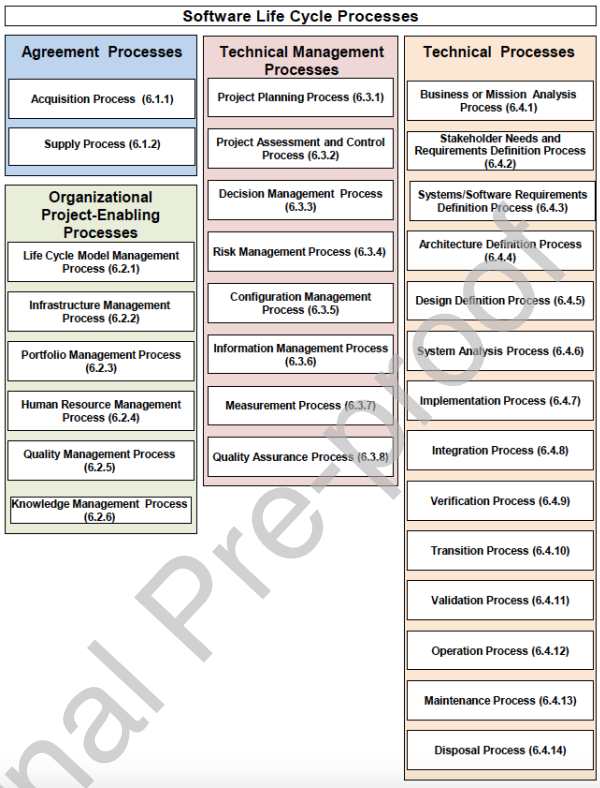

Figure 1. ISO/IEC/IEEE 12207 Software life cycle processes

As mentioned in the Introduction section, in this research we focus on the project management processes. Technical management is the application of technical and administrative resources to plan, organize and control engineering functions [31]. These processes are concerned with managing the resources and assets allocated by organization management and with applying them to fulfil the agreements into which the organization enter. The Technical Management processes are used to establish and perform technical plans for the project (in terms of cost, timescales and achievements); manage information across the technical team; assess technical progress against the plans for the software system, products or services; control technical tasks through to completion; and aid in decision-making about corrective actions that recover shortfalls in progress. Table 1 presents the ISO/IEC/IEEE 12207 Technical Management Processes and their purposes.

Table 1. ISO/IEC/IEEE 12207 Technical Management Processes and their purposes

Technical Management Process	Purpose
Project Planning process	To produce and coordinate effective and workable plans. This process determines the scope of the project management and technical activities, identifies process outputs, tasks and deliverables, establishes schedules for task conduct, including achievement criteria, and required resources to accomplish tasks.
Project assessment and control process	To assess if the plans are aligned and feasible; determine the status of the project, technical and process performance; and direct execution to help ensure that the performance is according to plans and schedules, within projected budgets, to satisfy technical objectives. This process also includes redirecting the project activities and tasks, as appropriate, to correct identified deviations and variations from other technical management or technical processes.
Decision Management process	To provide a structured, analytical framework for objectively identifying, characterizing and evaluating a set of alternatives for a decision at any point in the life cycle and select the most beneficial course of action.
Risk Management process	To identify, analyse, treat and monitor the risks throughout the life cycle of a system product or service. It can be applied to risks related to the acquisition, development, maintenance or operation of a system.
Configuration Management process	To manage and control system elements and configurations over the life cycle.
Information Management process	To generate, obtain, confirm, transform, retain, retrieve, disseminate and dispose of information, to designated stakeholders. Information includes technical, project, organizational, agreement, and user information. Information is often derived from data records of the organization, system, process, or project.
Measurement process	To collect, analyse, and report objective data and information to support effective management and demonstrate the quality of the products, services, and processes.
Quality Assurance process	To help ensure the effective application of the organization's Quality Management process to the project. Quality Assurance focuses on providing confidence that quality requirements will be fulfilled.

2.2 ISO/IEC TR 29110-5-1-2

The ISO/IEC TR 29110-5-1-2 standard [25] is aimed at providing a management and engineering guide, which is applicable to the vast majority of small and VSEs that do not develop critical software. This standard defines two processes, Software Implementation and Project Management. The purpose of the Software Implementation process is the systematic performance of the analysis, design, construction, integration, and tests activities for new or modified software products according to the specified requirements. The purpose of the Project Management process is to establish and carry out in a systematic way the tasks of the software implementation project, which allows complying with the project's objectives in the expected quality, time, and cost. Table 2 presents the four ISO/IEC TR 29110-5-1-2 Project Management activities and their goals.

Table 2. ISO/IEC TR 29110-5-1-2 Project Management Activities and their goals

Project Management Activity	Activity Goal
PM.1 Project Planning	To document the planning details needed to manage the project.
PM.2 Project Plan Execution	To implement the documented plan on the project.
PM.3 Project Assessment and Control	To evaluate the performance of the plan against documented commitments.
PM.4 Project Closure	To provide the project's documentation and products in accordance with contract requirements.

3 Agile Metrics to support Monitoring and Control processes

Using Agile means looking at new metrics that matter to both the team and management. These metrics matter because they focus on customer value. One problem with status reporting is the team's ability to predict completion. Metrics for agile projects contain meaningful information that provide a historical track record. Project teams can use such data for improved forecasts and decision-making [32], [33]. Agile favours empirical and value-based measurements instead of predictive measurements [29].

The definition and use of metrics can be helpful to demonstrate the progress of the team. It is true that the need for metrics will depend on each particular organization and work team. In any case, the first step for defining metrics is to identify the factors that contribute to valuable metrics. Four factors should be considered [34], [35]:

- Raise Warnings: metrics should warn when certain number is reached, in a good way or in a bad way but they should help to see that something happened.
- Drive Behaviour: metrics should have an impact in the people behaviour, should make members feel willing for a change.
- Teach: metrics should help to understand what's going on. They should help to learn and to understand how the system works.
- Expire or Recycle: metrics should be replaced when they are old, or at least, they should be recycled. They have to be checked periodically to find out if they still make sense.

Different authors have provided Agile metrics [3], [6], [7], [10], [15], [16], [36]–[38]. Some studies have arisen insights about their usefulness when deploying monitoring and control best practices in Agile teams [20], [21], [39]. Table 3 collects the Agile metrics that could be put in practice when implementing monitoring and control activities.

Table 3. Agile metrics and their usefulness for Monitoring and Control

Agile metric	Description	Value when Monitoring and Control
Time in status	Each task can go through different statuses such as "In Progress", "In Code Review", "Blocked", "Stopped Progress", etc. This metric shows the average time spent in each of these statuses.	With this metric, the team can detect patterns over the time. It is useful when the team has statuses that are queues in the workflow. Then, it is possible to see how harmful queues are for the system. If instead of in the status "Feedback" the task had been in the status "Ready for code review", this would mean that it takes a lot of time for the team to review each other code.
Flow efficiency	Given a task, Flow efficiency is calculated based on the amount of active time used in "working" statuses and the amount of non-active time in "waiting" statuses. Formula is [Work time / (Work time + Wait time)] * 100 Normally a good flow efficiency starts from 40%.	This metric can be useful to measure how efficient is the team and how harmful can be certain problems in the system. It can start creating awareness for the team to actually be able to finish a task with no interruptions or problems.
Cycle time	Cycle time is the amount of time spent since the team started to work on the task. That is, since the task was moved to "In Progress" status.	This metric provides how long it takes to complete a specific task from the beginning to the end.
Lead time	Lead time is the amount of time spent since the team got the request. That is, since the work item was introduced into the system.	This metric provides the time from the moment the customer places an order to the moment it is ready for delivery. It is very useful to see if the Product Owner is creating tasks too in advance, with the consequence of oversizing the backlog.
Reopens	This metric shows how many tasks were reopened during the cycle time period. Reopens can come from other developers during code reviews or from the QA during the testing.	It can be quite useful for a team to see the reopens over the periods. For example, when a team is rushing to deliver a result without paying too much attention on the development, it could happen that the QA needs to reopen tasks to correct detected problems that are breaking the application.
Tasks finished flow comparison	Given the number of tasks finished, this metric shows how many of them were stopped or blocked at some point during the development and how many were not.	Aspects like context switching can be reflected here, as the more context switching the team has, the more times the team has to stop tasks already started in order to start others.
Time spent extremes	This metric shows the tasks with most time spent in statuses where there is an active work being done (like "In Progress") and most time spent in statuses where there is no active work being done (like "Stopped Progress").	This information can be useful in a retrospective meeting, where conflictive tasks could be identified.

There exist software support tools that can manage large volumes of data and offer multiple views of the progress of the project. These tools can be used to analyse and graphically represent the values for the established metrics in the team. They provide a set of charts that support the analyses of the team performance metrics in Table 3 and facilitate decision-making. Some of the most useful charts are collected in Table 4.

Table 4. Agile charts and their usefulness for Monitoring and Control

Agile chart	Description	Value when Monitoring and Control
Flow Efficiency	It represents the ratio between value-adding time and the lead time (the frame between the order and delivery) required to complete a process.	This chart is quite good to represent tasks that have been waiting for a long time in the backlog, as well as tasks that once they were started they were never finished because the team switched focus.
Cumulative Flow diagram	It is an area graph that depicts the number of tasks in each status at the end of each day and enables seeing how they accumulate. The x-axis shows a sequence of days and the y-axis shows the number of tasks that were in a specific workflow status.	This diagram can show easily the health of the process. It shows arrivals, time in queue, quantity in queue and departures. The team can observe issues such as if the backlog grows more than it finishes tasks, or if the development process suffers from testing bottlenecks.
Throughput chart	It depicts the average number of tasks processed per time unit. The x-axis shows the time and the y-axis shows how many tasks were finished.	This chart can show if sprints are waterfall sprints. A waterfall sprint is a sprint in which all tasks are closed during the last days. It can show the waterfall pattern, that is, how often the team finishes tasks. Does it finish on batches of sprints, or does it daily?
Work In Progress (WIP) Run	It shows how many tasks are in progress (y-axis) every time unit (x-axis). If the team has defined a WIP limit, it will be able to see if this WIP limit is being respected or not.	Using this chart during a retrospective, the team can see how many activities has been working on at the same time during the sprint. It can show the ability of the team to not accumulate too much work in progress.
Scatterplot chart	It depicts the cycle time of all finished tasks. Each dot represents a task. The x-axis shows when the task was finished. The y-axis shows how long it took to be finished. This time to completion will depend on the different workflow statuses selected.	The scatterplot chart gives great visibility of the cycle times and the percentiles of them. For instance, it is not the same to know that the average cycle time is 10 days, that to know that 80% of cycle times is 7 days and 20% is 15 days.
Aging Work in Progress	It helps to visualize how tasks are progressing from the initial to the final status of the flow.	This chart gives visibility of the tasks that are not finished, and in which workflow status they are waiting.
Heat map	It is a graphical representation of the most common workflow statuses.	This chart can spot issues such as QA bottlenecks or problems with releases. For instance, if the team is not able to release something as soon as it is finished, the workflow status that represents this situation will start changing the colour.

Next section describes how the introduction of these metrics and charts in an Agile team can facilitate the achievement of the project monitoring and control best practices recommended by the two targeted ISO standards.

4 Conformance with targeted ISO standards

This section describes how the deployment of the processes for project monitoring and control in the targeted ISO standards can be supported by the Agile metrics and charts presented in the former section. Our research method consisted of two different stages. During the first stage, we selected the monitoring and control processes contained in each of the two targeted standards: ISO/IEC/IEEE 12207 and ISO/IEC TR 29110-5-1-2. The selection was made by comparing the process names and purposes. If these two fields were clearly related to any project monitoring and control issue, then, the process was considered for the study. Five ISO/IEC/IEEE 12207 processes and one ISO/IEC TR 29110-5-1-2 process were selected for next stage.

During the second stage, we looked for conformance to the selected processes. In order to claim conformance, ISO/IEC/IEEE 12207 defines two criteria:

- Claiming *full conformance to outcomes* asserts that all of the required outcomes of the declared set of processes are achieved.
- Alternatively, claiming *full conformance to tasks* asserts that all of the requirements of the activities and tasks of the declared set of processes are achieved.

In our research, and with the main goal of performing an in-depth study, by analysing each activity and task of the selected processes, we followed the second criterion to claim conformance to tasks (and activities). Next sub-sections present the results of this analysis.

4.1 Conformance with ISO/IEC/IEEE 12207

From the eight process in the ISO/IEC/IEEE 12207 Technical Management process group, we found relations with five processes: *Project planning*, *Project assessment and control*, *Decision management*, *Information management* and *Measurement*. Conformance with these processes is presented in the next five subsections.

4.1.1 Project planning process

Table 5 lists the activities and tasks proposed by the Project planning process.

Table 5. Project planning process activities and tasks

Activity	Task
a) Define the project	1) Identify the project objectives and constraints. NOTE 1 Objectives and constraints include performance and other quality aspects, cost, time and customer and user satisfaction. Each objective is identified with a level of detail that permits selection, tailoring and implementation of the appropriate processes and activities. NOTE 2 ISO/IEC 15026 Systems and software assurance, ISO/IEC 27001 Information Security Management System and ISO/IEC 27036, Information Security for Supplier Relationships, provide additional guidance on objectives and constraints related to assurance and security.

Activity	Task
	2) Define the project scope as established in the agreement. NOTE This includes the relevant activities required to satisfy business decision criteria and complete the project successfully. A project can have responsibility for one or more stages in the complete software system life cycle. Project Planning includes defining appropriate actions for maintaining project plans, performing assessments and controlling the project.
	3) Define and maintain a life cycle model that is comprised of stages using the defined life cycle models of the organization. NOTE ISO/IEC TS 24748-1 provides detailed information regarding life cycle stages and the definition of an appropriate life cycle model. It defines a general set of exemplar system life cycle stages, including Concept, Development, Production, Utilization, Support and Retirement. It also identifies a generic exemplar set of software life cycle stages, including Needs determination, Concept exploration and definition, Demonstration and evaluation, Engineering/development, Production/manufacturing, Deployment/sales, Operations, Maintenance and support, and Retirement.
	4) Establish a work breakdown structure (WBS) based on the deliverable products or the evolving architecture of the software system. NOTE 1 Each element of the software system architecture, and appropriate processes and activities, are described with a level of detail that is consistent with identified risks. Related tasks in the work breakdown structure are grouped for performance. Project tasks identify work items being developed or produced. The Practice Management Standard for Work Breakdown Structures of the Project Management Institute (PMI) contains additional details on WBSs. NOTE 2 For projects with agile or iterative methods, a WBS element can correspond to the primary features, from a user perspective, to be produced during iterations.
	5) Define and maintain the processes that will be applied on the project. NOTE 1 These processes are based on the defined processes of the organization (see Life Cycle Model Management process). Annex A contains information on tailoring that can be used to address project-specific needs. The definition of the processes includes the entry and exit criteria, inputs, process sequence constraints (predecessor/successor relationships), process concurrency requirements (what processes and tasks are to be worked concurrently with other process area tasks or activities), Measures of Effectiveness/Measures of Performance attributes, and scope and cost parameters (for critically important cost estimation). NOTE 2 Identifying interfaces with other projects or organizational units is addressed through the Portfolio Management process.
b) Plan project and technical management	1) Define and maintain a project schedule based on management and technical objectives and work estimates. NOTE This includes definition of the duration, relationship, dependencies and sequence of activities, achievement milestones, resources employed and the reviews and schedule reserves for risk management necessary to achieve timely completion of the project.
	2) Define achievement criteria for the life cycle stage decision gates, delivery dates and major dependencies on external inputs or outputs. NOTE The time intervals between internal reviews are defined in accordance with organizational policy on issues such as business and system criticality, schedule and technical risks.
	3) Define the costs and plan a budget. NOTE Budgeted costs are based on the schedule, software size and complexity estimates, labor estimates, infrastructure costs, procurement items, acquired service and enabling system estimates, and budget reserves for risk management.

Activity	Task
	4) Define roles, responsibilities, accountabilities, and authorities. NOTE This includes defining the project organization, staff acquisitions, and the development of staff skills. Authorities include, as appropriate, the legally responsible roles and individuals, e.g., design authorization, safety authorization, and those responsible for applicable certifications or accreditations.
	5) Define the infrastructure and services required. NOTE This includes defining the capacity needed, its availability and its allocation to project tasks. Infrastructure includes facilities, services, tools, communications, and information technology assets. The requirements for enabling systems and services for each life cycle stage are also specified.
	6) Plan the acquisition of materials and enabling systems and services supplied from outside the project. NOTE 1 This includes, as necessary, plans for solicitation, supplier selection, acceptance, contract administration and contract closure. The agreement processes are used for the planned acquisitions. NOTE 2 ISO/IEC 27036, Information security for supplier relationships, provides guidance for acquisition of infrastructure and services.
	7) Generate and communicate a plan for project and technical management and execution, including reviews. NOTE 1 Technical planning for the software system is often captured in a Systems Engineering Management Plan (SEMP) or a Software Engineering Management Plan or a Software Development Plan (SDP). ISO/IEC/IEEE 24748-5 provides more detail on software engineering technical management planning and includes an annotated outline for an SDP. Planning for the project is often captured in a Project Management Plan. ISO/IEC/IEEE 16326 provides more detail on project planning. NOTE 2 The strategy activities and tasks from each of the other processes provide inputs and are integrated in the Project Planning process. The Project Assessment and Control process is used to help ensure that the plans are integrated, aligned, and feasible.
c) Activate the project	1) Obtain approval to start the project. NOTE Approval to start (authorization to proceed) is provided through the Portfolio Management process.
	2) Submit requests and obtain commitments for necessary resources to perform the project. NOTE This includes access to enabling systems or services.
	3) Implement project plans.

The first activity of this process is *Define the project*. Agile metrics such as "flow efficiency" or "task in status" can support task 3 *Define and maintain a life cycle model that is comprised of stages using the defined life cycle models of the organization*, as they require having defined the workflow with all the statuses a task should go through. The feedback provided by Agile metrics can also be useful to re-plan the work breakdown structure (WBS) based on the deliverable products as recommended by task 4: *"For projects with agile or iterative methods, a WBS element can correspond to the primary features, from a user perspective, to be produced during iterations"*. Finally, the definition of Agile metrics is fully aligned by task 5 *Define and maintain the processes that will be applied on the project*, as it considers these kind of measures as part of the processes: *"The definition of the processes includes […] Measures of Effectiveness/Measures of Performance attributes, and scope and cost parameters"*.

Conformance to the second activity *Plan project and technical management* was also detected. Agile metrics and charts can facilitate the maintenance of the project schedule as proposed by task 1 *Define and maintain a project schedule based on*

management and technical objectives and work estimates. Moreover, some metrics such as "Lead time" or "Cycle time" are related to the definition of *"achievement criteria for the life cycle stage decision gates"* as demanded by task 2. In addition, according to task 7 *Generate and communicate a plan for project and technical management and execution, including reviews*, Agile metrics can provide great value when defining the plan for project and technical management and execution.

4.1.2 Project assessment and control process

Table 6 lists the activities and tasks to be implemented in accordance with applicable organization policies and procedures with respect to the Project assessment and control process.

Table 6. Project assessment and control process activities and tasks

Activity	Task
a) Plan for project assessment and control	1) Define the project assessment and control strategy. NOTE The strategy identifies the expected Project Assessment and Control activities, including planned assessment methods and timeframes, and necessary management and technical reviews.
b) Assess the project	1) Assess alignment of project objectives and plans with the project context.
	2) Assess management and technical plans against objectives to determine adequacy and feasibility.
	3) Assess project and technical status against appropriate plans to determine actual and projected cost, schedule, and performance variances.
	4) Assess the adequacy of roles, responsibilities, accountabilities, and authorities. NOTE This includes assessment of the adequacy of personnel competencies to perform project roles and accomplish project tasks. Objective measures are used wherever possible, e.g., efficiency of resource use, project achievement.
	5) Assess the adequacy and availability of resources. NOTE Resources include infrastructure, personnel, funding, time, or other pertinent items. This task includes evaluating the reuse of existing processes and infrastructure resources, and confirming that intra-organizational commitments are satisfied.
	6) Assess progress using measured achievement and milestone completion. NOTE This includes collecting and evaluating data for labor, material, service costs, and technical performance, as well as other technical data about objectives, such as affordability. These are compared against measures of achievement. This includes conducting effectiveness assessments to determine the adequacy of the evolving software system against requirements. It also includes the readiness of enabling systems to deliver their services when needed.
	7) Conduct required management and technical reviews, audits and inspections. NOTE These are formal or informal, and are conducted to determine readiness to proceed to the next stage of the life cycle or project milestone, to help ensure that project and technical objectives are being met, or to obtain feedback from stakeholders.
	8) Monitor critical processes and new technologies. NOTE This includes identifying and evaluating technology maturity and feasibility of technology insertion. Technology maturity is the readiness of a technology for operational use, and is often measured on a scale from low (exists as a concept only) to high (proven in operational use).

Activity	Task
	9) Analyze measurement results and make recommendations. NOTE Measurement results are analyzed to identify deviations, variations or undesirable trends from planned values that include potential concerns, and to make appropriate recommendations for corrections or preventive actions. This includes, where appropriate, statistical analysis of measures that indicates trends, e.g., fault density to indicate quality of outputs, distribution of measured parameters that indicate process repeatability.
	10) Record and provide status and findings from assessment tasks. NOTE These are generally designated in the agreement, policies and procedures.
	11) Monitor process execution within the project. NOTE This includes the analysis of process measures and review of trends with respect to project objectives. Any improvement actions identified can be handled through the Quality Assurance process, the Quality Management process, or the Life Cycle Model Management process.
c) Control the project	1) Initiate necessary actions needed to address identified issues. NOTE 1 This task occurs when project or technical achievement is not meeting planned targets. This includes preventive, corrective, and problem resolution actions. Actions generally require replanning or reassignment of personnel, tools and infrastructure assets when inadequacy or unavailability has been detected, or when project or technical achievement exceeds targets or plan. They often impact the cost, schedule, or technical scope or definition. Actions sometimes require changes to the implementation and execution of the life cycle processes. NOTE 2 Actions are recorded and reviewed to confirm their adequacy and timeliness.
	2) Initiate necessary project replanning. NOTE 1 Project replanning is initiated when project objectives or constraints have changed, or when planning assumptions are shown to be invalid. NOTE 2 Any change that requires a change to the agreement between acquirer and supplier invokes the Acquisition and Supply processes.
	3) Initiate change actions when there is a contractual change to cost, time or quality due to the impact of an acquirer or supplier request. NOTE This includes consideration of modified terms and conditions for supply or initiating new supplier selection, which invokes the Acquisition and Supply processes.
	4) Authorize the project to proceed toward the next milestone or event, if justified. NOTE The Project Assessment and Control process is used to reach agreement on milestone completion.

The first activity of this process is *Plan for project assessment and control*. The definition of Agile metrics is fully aligned to task 1 *Define the project assessment and control strategy*: *"The strategy identifies the expected Project Assessment and Control activities, including planned assessment methods and timeframes, and necessary management and technical reviews"*, as these metrics can be considered a robust assessment method for management and technical review.

Full conformance to the second activity *Assess the project* was detected as most of the tasks it proposes can be fulfilled by applying the Agile metrics and charts in section 3. Some examples of full relation can be found in task 2 *Assess management and technical plans against objectives to determine adequacy and feasibility* and in task 3 *Assess project and technical status against appropriate plans to determine actual and projected cost, schedule, and performance variances*. Task 4 *Assess the adequacy of roles, responsibilities, accountabilities, and authorities* recommends the "*assessment of the adequacy of personnel competencies to perform project roles and accomplish project tasks*" and the use wherever possible of "*Objective measures […] e.g.,*

efficiency of resource use, project achievement". Task 6 is one of the most benefited from the implementation of Agile metrics. ISO/IEC/IEEE 12207 explicitly mentions "*Assess progress using measured achievement and milestone completion. This includes collecting and evaluating data for labor, material, service costs, and technical performance, as well as other technical data about objectives, such as affordability. These are compared against measures of achievement*". Task 7 can be also fully achieved when introducing Agile metrics for management or technical reviews: *"Conduct required management and technical reviews, audits and inspections. These are formal or informal, and are conducted to determine readiness to proceed to the next stage of the life cycle or project milestone, to help ensure that project and technical objectives are being met, or to obtain feedback from stakeholders"*. Task 9 proposes *Analyze measurement results and make recommendations*. From the analysis of Agile metrics, the team can identify deviations, variations or undesirable trends from planned values that include potential concerns, and to make appropriate recommendations for corrections or preventive actions. This task recommends "*statistical analysis of measures that indicates trends, e.g., […] distribution of measured parameters that indicate process repeatability*". Finally, task 11 *Monitor process execution within the project* can be considered fully achieved, as Agile metrics and charts are designed to satisfy the goal of this task *"analysis of process measures and review of trends with respect to project objectives"*.

The third and last activity of this process is *Control the project*. Some tasks can also be supported by the introduction of Agile metrics and charts. When project or technical achievement is not meeting planned targets, task 1 occurs: *Initiate necessary actions needed to address identified issues*. Agile metrics can be very useful to validate the need of project replanning, which is the goal of task 2 *Initiate necessary project replanning*, *"Project replanning is initiated when project objectives or constraints have changed, or when planning assumptions are shown to be invalid"*.

4.1.3 Decision management process

Table 7 lists the activities and tasks recommended by the Decision management process.

Table 7. Decision management process activities and tasks

Activity	Task
a) Prepare for decisions	1) Define a decision management strategy. NOTE A decision management strategy includes the identification of roles, responsibilities, accountabilities, and authorities. The strategy considers the need for obtaining information input and for returning a timely decision. It includes the identification of decision categories and a prioritization scheme. Decisions often arise as a result of an effectiveness assessment, a technical trade-off, a problem needing to be solved, an action needed as a response to risk exceeding the acceptable threshold, or a new opportunity or approval for project progression to the next life cycle stage. Organization or project guidelines determine the degree of rigor and formality to apply to the decision analysis.
	2) Identify the circumstances and need for a decision. NOTE Problems or opportunities and the alternative courses of action that will resolve their outcome are recorded, categorized and reported.

Activity	Task
	3) Involve relevant stakeholders in the decision-making in order to draw on experience and knowledge. NOTE It is good practice to identify the subject matter expertise needed for the analysis and the decision.
b) Analyze the decision information	1) Select and declare the decision management strategy for each decision. NOTE The degree of rigor required to resolve these problems or opportunities is determined, as well as the data and system analysis needed for evaluating the alternatives. Define the timeframe to reach a decision.
	2) Determine desired outcomes and measurable selection criteria. NOTE The desired value for quantifiable criteria and the threshold value(s) beyond which the attribute will be unsatisfactory are determined, as well as weighting factors for the criteria.
	3) Identify the trade space and alternatives. NOTE If a large number of alternatives exist, they are qualitatively screened to reduce alternatives to a manageable number for further detailed systems analysis. This screening is often based on qualitative assessments of such factors as risk, cost, schedule, and regulatory impacts.
	4) Evaluate each alternative against the criteria. NOTE The System Analysis process is used, as necessary, to quantify specific criteria for each trade alternative to be evaluated. This includes new design parameters, different architecture characteristics, and range of values for critical quality characteristics. The System Analysis process assesses the range of parameter variations in order to obtain a sensitivity analysis for each of the trade alternatives evaluated. These results are used to establish the feasibility of the various trade alternatives.
c) Make and manage decisions	1) Determine preferred alternative for each decision. NOTE Alternatives are evaluated quantitatively, using the selection criteria. The selected alternative generally provides an optimization of, or improvement in, an identified decision.
	2) Record the resolution, decision rationale, and assumptions.
	3) Record, track, evaluate and report decisions. NOTE 1 This includes records of problems and opportunities and their disposition, as stipulated in agreements or organizational procedures and in a manner that permits auditing and learning from experience. NOTE 2 This allows the organization to confirm that problems have been effectively resolved, that adverse trends have been reversed, and that advantage has been taken of opportunities.

The first activity of the Decision management process is *Prepare for decisions*. It recommends two tasks that can be facilitated by Agile metrics. Task 1 is *Define a decision management strategy* and it mentions "*The strategy considers the need for obtaining information input and for returning a timely decision. […]. Decisions often arise as a result of an effectiveness assessment*". Similarly, Agile metrics and charts can help to task 2, *Identify the circumstances and need for a decision*.

The second activity is *Analyze the decision information*. Agile metrics and charts are conformant to the tasks 1 and 2 this activity defines. Task 1 is *Select and declare the decision management strategy for each decision*. The standard recommends determining *"the data and system analysis needed for evaluating the alternatives"*. Moreover, task 2 *Determine desired outcomes and measurable selection criteria* also recommends determining *"the desired value for quantifiable criteria and the threshold value(s) beyond which the attribute will be unsatisfactory, as well as weighting factors for the criteria"*.

The implementation of Agile metrics and charts can also support the final activity in this process: *Make and manage decisions*. Task 1 *Determine preferred alternative for each decision* could be easily achieved when using objective data.

4.1.4 Information management process

Table 8 shows the activities and tasks that the Information management process defines.

Table 8. Information management process activities and tasks

Activity	Task
a) Prepare for information management	1) Define the strategy for information management. NOTE Information about the same topic can be developed in different ways at different points in the life cycle and for different audiences.
	2) Define the items of information that will be managed. NOTE This includes the information that will be managed during the software life cycle and possibly maintained for a defined period beyond. This is done according to organizational policy, agreements, or legislation.
	3) Designate authorities and responsibilities for information management. NOTE Due regard is paid to information and data legislation, security and privacy, e.g., ownership, agreement restrictions, rights of access to data and ownership of data, intellectual property and patents. Where restrictions or constraints apply, information is identified accordingly. Staff members with knowledge of such items of information are informed of their obligations and responsibilities.
	4) Define the content, formats and structure of information items. NOTE The information originates and terminates in many forms (e.g., audiovisual, textual, graphical, numerical) and mediums (e.g., electronic, printed, magnetic, optical). Organization constraints, e.g., infrastructure, inter-organizational communications, and distributed project workings, are taken into account. Relevant information item standards and conventions are used according to policy, agreements and legislation constraints.
	5) Define information maintenance actions. NOTE Information maintenance includes status reviews of stored information for integrity, validity and availability. It also includes any needs for replication or transformation to an alternative medium, as necessary, either to retain infrastructure as technology changes so that archived media can be read or to migrate archived media to newer technology.
b) Perform information management	1) Obtain, develop, or transform the identified items of information. NOTE This includes collecting the data, information, or information items from appropriate sources (e.g., resulting from any life cycle process), and writing, illustrating, or transforming it into usable information for stakeholders. It includes reviewing, validating, and editing information per information standards.
	2) Maintain information items and their storage records, and record the status of information. NOTE 1 Information items are maintained according to their integrity, security and privacy requirements. The status of information items is maintained, (e.g., version description, date of issue or validity date, record of distribution, security classification). Legible information is stored and retained in such a way that it is readily retrievable. NOTE 2 The source data and tools used to transform information, along with the resulting documentation is placed under configuration control in accordance with the Configuration Management process. ISO/IEC/IEEE 26531 provides requirements for content management systems useful for life cycle information and documentation.

Activity	Task
	3) Publish, distribute or provide access to information and information items to designated stakeholders. NOTE Information is provided to designated stakeholders in an appropriate form, as required by agreed schedules or defined circumstances. Information items include documentation used for certification, accreditation, license or assessment ratings, as required.
	4) Archive designated information. NOTE Archiving is done in accordance with the audit, knowledge retention, and project closure purposes. The media, location and protection of the information are selected in accordance with the specified storage and retrieval periods, and with organization policy, agreements and legislation. Arrangements are put in place to retain necessary information items after project closure.
	5) Dispose of unwanted, invalid or unvalidated information. NOTE This is done according to organization policy, and security and privacy requirements.

The first of the two activities of this process is *Prepare for information management*. The representation and audience of each Agile metric or chart should be defined as proposed by some of the tasks in this activity. According to task 1 *Define the strategy for information management*, information about project performance can be developed in different ways at different points in the life cycle and for different audiences. Task 2 recommends to *define the items of information that will be managed*. Team members with knowledge of such Agile metrics are usually informed of their obligations and responsibilities, as proposed by task 3 *Designate authorities and responsibilities for information management*.

The second activity of this process is *Perform information management*. One of the main goals of defining Agile metrics is totally aligned to task 1 *Obtain, develop, or transform the identified items of information*, as its description explicitly mentions: "*This includes collecting the data […] from appropriate sources (e.g., resulting from any life cycle process), and writing, illustrating, or transforming it into usable information for stakeholders"*. The use of software tools can greatly facilitate the fulfilment of task 2 *Maintain information items and their storage records, and record the status of information*. The standard recommends the use of *"transform information tools to store and retain legible information in such a way that it is readily retrievable"*. The use of software tools can also facilitate conformance to task 3 *Publish, distribute or provide access to information and information items to designated stakeholders*, as designated team members and stakeholders can access to Agile metrics according to agreed circumstances.

4.1.5 Measurement process

Table 9 lists the activities and tasks defined by the Measurement process.

Table 9. Measurement process activities and tasks

Activity	Task
a) Prepare for measurement	1) Define the measurement strategy.
	2) Describe the characteristics of the organization that are relevant to measurement, such as business and technical objectives.

Activity	Task
	3) Identify and prioritize the information needs. NOTE The information needs are based on the organization's business objectives, the project objectives, identified risks, and other items related to project decisions. Measurements can relate to projects, processes, products, or decisions.
	4) Select and specify measures that satisfy the information needs. NOTE Measures are defined that are verifiable and cost-effective.
	5) Define data collection, analysis, access, and reporting procedures.
	6) Define criteria for evaluating the information items and the Measurement process.
	7) Identify and plan for the necessary enabling systems or services to be used.
b) Perform measurement	1) Integrate manual or automated procedures for data generation, collection, analysis and reporting into the relevant processes. NOTE This task can involve change impacts to other life cycle processes to accomplish procedural integration.
	2) Collect, store, and verify data.
	3) Analyze data and develop information items.
	4) Record results and inform the measurement users. NOTE The measurement analyses results are reported to relevant stakeholders in a timely, usable fashion to support decision making and assist in corrective actions, risk management, and improvements. Results are reported to decision process participants, technical and management review participants, and product and process improvement process owners.

The Measurement process proposes *Prepare for measurement* as the first activity. The definition and introduction of Agile metrics is totally aligned to the following tasks of this activity. Task 1 is *Define the measurement strategy* and task 2 is *Describe the characteristics of the organization that are relevant to measurement, such as business and technical objectives*. Agile metrics to be measured should be relevant and aligned to the organizational objectives. However, introducing many metrics willing to control almost everything is not always the best solution. Metrics should be prioritized. If this is done *"based on the organization's business objectives, the project objectives, identified risks, and other items related to project decisions"*, then task 3 *Identify and prioritize the information needs* will be fulfilled as well. Then, by applying the suitable metrics in section 3, the team will have achieved task 4 *Select and specify measures that satisfy the information needs* and task 5 *Define data collection, analysis, access, and reporting procedures*.

Once the most convenient Agile metrics and charts are identified, agreed and implemented is time to *Perform measurement*, the second activity in this process. Software tools can greatly facilitate task 1 *Integrate manual or automated procedures for data generation, collection, analysis and reporting into the relevant processes*, task 2 *Collect, store, and verify data*. The notations and graphical representations provided by these Agile software tools enormously support task 3 *Analyze data and develop information items*, as the measurement analyses results are *"reported to relevant stakeholders in a timely, usable fashion to support decision making and assist in corrective actions, risk management, and improvements"*.

4.2 Conformance to ISO/IEC TR 29110-5-1-2

From the four activities of the ISO/IEC TR 29110-5-1-2 Project Management process, we found relations with two activities: *Project plan execution* and *Project assessment and control*. Conformance with these activities is presented in next two subsections.

4.2.1 Project plan execution activity

Table 10 lists the tasks of the activity Project plan execution.

Table 10. Project plan execution activity tasks

Task
PM.2.1 Monitor the Project Plan execution and record actual data in Progress Status Record.
PM 2.2 Analyse and evaluate the Change Request for cost, schedule and technical impact. The Change Request can be initiated externally by the Customer or internally by the Work Team. Update the Project Plan, if the accepted change does not affect agreements with Customer. Change Request, which affects those agreements, needs to be negotiated by both parties.
PM.2.3 Conduct revision meetings with the Work Team, identify problems, review risk status, record agreements and track them to closure.
PM.2.4 Conduct revision meetings with the Customer, record agreements and track them to closure. Change Request initiated by Customer or initiated by Work Team, which affects the Customer, needs to be negotiated to reach acceptance of both parties. If necessary, update the Project Plan according to new agreement with Customer.
PM.2.5 Perform backup according to the Version Control Strategy.
PM.2.6 Perform Project Repository recovery using the Project Repository Backup, if necessary.

Three tasks of this activity can be supported by the use of Agile metrics. The first one is task *PM.2.1 Monitor the Project Plan execution and record actual data in Progress Status Record*. Agile metrics used by the team provide great value for monitoring the project plan execution. Moreover, these metrics and charts can be presented to the designated members of the team or even to external stakeholders, such as the customer when is acting as the product owner. Then, task *PM.2.3 Conduct revision meetings with the Work Team, identify problems, review risk status, record agreements and track them to closure*, would be fulfilled when using the Agile metrics and charts to identify problems and review risk status, which is indeed one of the main reasons to introduce this kind of indicators. Similarly, task *PM.2.4 Conduct revision meetings with the Customer, record agreements and track them to closure* could be supported by the information provided by the Agile indicators.

4.2.2 Project assessment and control activity

Table 11 lists the tasks of the activity Project assessment and control.

Table 11. Project assessment and control activity tasks

Task
PM.3.1 Evaluate project progress with respect to the Project Plan, comparing: - actual Tasks against planned Tasks - actual results against established project Objectives - actual resource allocation against planned Resources - actual cost against budget estimates - actual time against planned schedule - actual risk against previously identified
PM.3.2 Establish actions to correct deviations or problems and identified risks concerning the accomplishment of the plan, as needed, document them in Correction Register and track them to closure.
PM.3.3 Identify changes to requirements and/or Project Plan to address major deviations, potential risks or problems concerning the accomplishment of the plan, document them in Change Request and track them to closure.

The evaluation of actual plan performance and progress against targets is the final goal of any well-defined Agile metric. And this exactly the goal of task *PM.3.1 Evaluate project progress with respect to the Project Plan*, comparing actual Tasks against planned Tasks, actual results against established project objectives or actual time against planned schedule, among other project management areas such as quality, risks or costs.

Agile metrics and charts can easily show technical performance deviations and problems and, consequently, appropriate corrective action can be early defined. This is the one of goals of task *PM.3.3 Identify changes to requirements and/or Project Plan to address major deviations, potential risks or problems concerning the accomplishment of the plan, document them in Change Request and track them to closure*, which achievement could be supported by the Agile metrics introduced in the work team.

5 Conclusion

In this paper, we have presented how by defining and using a set of Agile metrics and charts, Agile mature companies can be also conformant with the best practices of some project management processes of the targeted ISO standards. Specifically, we have found conformance with five Technical Management processes of the ISO/IEC/IEEE 12207 standard and with two activities of the Project Management process of the ISO/IEC TR 29110-5-1-2 standard. We believe that our findings may be of the interest of those companies that have adopted an Agile approach, but at the same time, need to work according to a process model established in the organization.

We have selected the ISO/IEC/IEEE 12207 standard because it is the wide-spread PRM considered by software companies that pretend to be certified according to ISO/IEC 33000 (SPICE). In addition, we have also considered the ISO/IEC TR 29110-5-1-2 standard to demonstrate that the introduction of Agile metrics would also be very useful for the VSEs that work according to the processes of this standard. There are other ISO standards, such as ISO 21500, that collect project management processes. In this research, we have not considered this standard because it does not define activities and tasks for each of the processes it contains.

It could seem that in Agile environments the topic of using data (beyond story points or velocity) is a bit of a taboo subject. We truly believe that "what cannot be seen does not exist". If a problem is not visible, then it does not exist. All the precise information collected from the Agile metrics and represented in charts is very useful for focusing on real issues. The best situation to help in a decision-making is to know if there was or not an improvement from past situations, and to see how the team improved the operational process. With Agile metrics, data is not an assumption. And it is much better to be driven by the power of proof than by assumptions. Data are the reality of the consequences of the team way of working, represented in figures. The team should be aware of how they are performing, because without measures it is really hard to find improvement opportunities. If the team is able to measure all the wastes, queues or steps in the process that are not providing value, the team could even be conscious of the economic consequences of its way of working.

During this research, we have also observed that the application of a set of Agile metrics to a specific set of processes in the life cycle could be used to facilitate reaching capability level 4 according to the SPICE process assessment model. This is left for a subsequent work.

Other future works will focus on the validation of the results obtained. We will, firstly, collect feedback from different Agile coaches in software development companies experienced in the deployment of ISO process models. Moreover, any comment or improvement suggestion both from Industry or Academy will be very welcome for refining the obtained results. The scope of our work is planned to be widened to other technical processes in the two targeted standards. Finally, we will consider other ISO process standards.

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Dear Editor,

Antonia Mas, Antoni-Lluís Mesquida and Marcos Pacheco, authors of this manuscript, declare that there is no conflict of interest.

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