Outcome Specification:

Competence Model for the Digital Transformation (CMDT)

Within the Erasmus+ Knowledge Alliance ProDiT – Projects for the Digital Transformation

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1. Summary

Competences are a combination of knowledge, skills, abilities and attitudes which allow persons are teams to perform a certain task. A set of competences owned by an individual or team or required for a certain work is called a competence profile. If the formulation of competences and competence profiles is formalized or standardized in a certain way, this formulation can be done based on a competence model. Competence models provide the syntax and semantic for the formulation of competences and competence profiles. They can also define how competences change or how competences interrelate.

Overall Goal: The digital transformation requires certain competences and new competences and competence profiles emerge during the digital transformation. In addition, the digital transformation provides new ways to build (digital, data driven) competence models, and to derive competence profiles from data. Furthermore, the change of competences (demand driven, from new forms of learning) is specifically relevant in the digital transformation. The goal of the research is to develop a digital competence model which supports the needs for working with competences and competence profiles in the digital transformation.

Purpose and Requirement Analysis: Typical use cases for a competence model for the digital transformation are:

- Describing the competence profile of an individual
- Planning the competence development of an individual or team, e.g. through training
- Deriving the competence requirements for a project team from a project description
- Optimizing the staffing and scheduling of projects based on competences
- Deriving the competence profile of a team from individual competence profiles
- Assessing the gap between two competence profiles, e.g. current competence profile and targeted future competence profile

Current State-of-the-Art: Competence models are intensively researched and used, there is a huge variety of approaches and models. Verbal descriptions and competence/skills catalogues with verbal descriptions are common. Skills are rated on (quantified) scales. More complex formal models exist but are less common.

Problem Statement: Existing competence models do not sufficiently support digital processing and operations (e.g. plus or minus), making them unsuitable for data-based approaches.

Research Plan: Key research questions are: What are the relevant competences for “Managing the Digital Transformation” (MDT)? And how can we reflect their dynamic change and their complexity?

Dissemination & Standardisation: Results are planned to be disseminated and standardized with the IEEE and IPMA.

Quality Evaluation: t.b.d.

Change History & Ownership:

Release V1.0: Initial version of the specification of the CMDT, OpenCoP on Competences for the Digital Transformation, 09.09.2022

Table of Content

2. Introduction to the Competence Model for the Digital Transformation (CMDT)

The Competence Model for the Digital Transformation (CMDT) is a formal definition and a guideline for the formalized, digital and quantifiable description of competence profiles, e.g:

- Competence profile of an individual
- Required competence profile for a task/job
- Competence gap (or delta), the difference between two competence profiles
- Competence development (e.g. increase, decrease) over time
- Competence profile of a team
- Required competence profile (of a team) for a project

The Competence Model for the Digital Transformation (CMDT) should support specific operations or calculations:

- Describing the competence profile of an individual
- Planning the competence development of an individual or team, e.g. through training
- Deriving the competence requirements for a project team from a project description
- Optimizing the staffing and scheduling of projects based on competences
- Deriving the competence profile of a team from individual competence profiles
- Assessing the gap between two competence profiles, e.g. current competence profile and targeted future competence profile

The main research topics in this context are:

- Literature review on existing competence models with the goal to develop a taxonomy of competence models
- Literature review on existing competence frameworks, catalogues and description with a focus on digital competences or digital transformation competences
- Concept for deriving the competence profile of a team from individual competence profiles in a formalized way, e.g. by “adding” competences. This is specifically complex for so-called “soft skills” which do not simply add up.
- Concept for deriving a required (team) competence profile from a project description, especially using automated methods (e.g. NLP, AI methods)
- Concept for assessing the difference between two competence profiles in a formal way, especially for calculating a quantified competence gap
- Validation of the concepts in the use case of an optimization of project staffing and staff scheduling, especially in the case of a modified Multi-Skill(ed) Resource Constrained Project Scheduling Problem (MS-RCPSP)
- Validation of the concepts in competence-based training and education

3. Description of the planned research

3.1 Overall Goal

The digital transformation requires certain competences and new competences and competence profiles emerge during the digital transformation. In addition, the digital transformation provides new ways to build (digital, data driven) competence models, and to derive competence profiles from data. Furthermore, the change of competences (demand driven, from new forms of learning) is specifically relevant in the digital transformation. The goal of the research is to develop a digital competence model which supports the needs for working with competences and competence profiles in the digital transformation.

3.2 Purpose and Requirement Analysis

The research about projects for the digital transformation covers different views on the topic, especially the project view, the people view, the organisational view, and the impact view. The research on the competence model for the digital transformation (CMDT) is a relevant part of the people view, addressing two research questions: What are the relevant competences for “Managing the Digital Transformation” (MDT)? And how can we reflect their dynamic change and their complexity?

Figure 1: People focus as aspect of the research on managing the digital transformation with projects

The purpose of the competence model for the digital transformation (CMDT) is to support project management and planning process, and especially the people and team development processes. Typical use cases for a competence model for the digital transformation are:

- Describing the competence profile of an individual
- Planning the competence development of an individual or team, e.g. through training
- Deriving the competence requirements for a project team from a project description
- Optimizing the staffing and scheduling of projects based on competences
- Deriving the competence profile of a team from individual competence profiles

- Assessing the gap between two competence profiles, e.g. current competence profile and targeted future competence profile.

3.3 Current State-of-the-Art

According to the European commission's definition, a competence indicates a "satisfactory state of knowledge, skills and attitudes and the ability to apply them in a variety of situations" [1]. According to the definition provided by [2], a project is supposed to deliver a "unique product, service, or result". Therefore, the team assigned to a project should possess certain competences based on the unique requirements and specific tasks of the project: a required competence profile for the project. Competence as a concept plays an important role in project management, since the definition of a required competence profile for a given project helps to staff projects correctly and to assemble project teams properly. The relevant state of the art includes research on project management, competence management and optimisation of staffing and scheduling. The following pages will provide an overview of the most relevant literature from each of these domains.

Projects, Project Success, Work Breakdown: Projects are constrained by various factors related to time, cost, quality and scope. A project's scope defines the type of work required to deliver project outcomes, which are usually broken down into specific work packages [2]. According to the International Project Management Association (IPMA), well-defined project scope boundaries help to delimit the required work and support better resource allocation. With respect to human resources, projects must be staffed with competent people and, due to the dynamic nature of the project's environment, staffing should be considered a continuous process which will evolve throughout the project's entire lifecycle [3]. According to [3], individual competence or team management are addressed by the people-focused project management approach. Relying on team competences is related to the uncertainty and complexity elements of project management, as well as from the required flexibility in projects, which is enhanced by having "competent and experienced people" involved which can react properly to uncertain situations [4]. Project success is not only defined by the immediate project outputs and deliverables but also by more long-term effects such as the development of the team's and, indeed, the entire organisation's competences [5].

Competences, Competence Profiles and Competence Models: The concept of competences is a very diverse research area with different approaches towards definition and modelling [6]–[12]. There is ongoing research on the differences between the terms "competence" and "competency", as highlighted in [12]. [7] define competences as "context-specific cognitive dispositions that are acquired and needed to successfully cope with certain situations or tasks in specific domains". This definition underlines the complexity of the concept as it incorporates context, cognitive aspects and task domains. Competence assessment contributes to optimizing and advancing training processes and systems. Evaluating competences may have different goals and focuses and therefore it is difficult and complicated to assess "learners'

baseline competences" [7]. Competences – especially in project management – are formulated as complex profiles which are based on competence models (formulated as the conceptual model of "competence" and standardized in competence catalogues, e.g. IPMA ICB [3]). One of the purposes of competence assessment is evaluating the gap between an "ideal" competence profile, which is required to execute the project work packages, and individual competence profiles, possessed by every member of a project team [13]. [14] highlight how assessing the gap between individual and project's competences will help to identify the training needs of a project's team members. In order to accurately evaluate this gap, a mathematical formalism should be applied. [9] have noted in their discussion of individual and group competences that although group competences are thought to be the sum of individual competences this definition "does not reflect the efficiencies gained or lost from such an aggregation". This is confirmed by [13], who stress the complex nature of operators (e.g., the "-" and "+" operators) applied to competence profile calculation. It can be concluded that neither the compilation of a team competence profile from individual competence profiles nor the calculation of the competence gap between different competence profiles is a solved scientific problem.

Staffing and Scheduling Optimization: The mapping of a team to a project in terms of time (scheduling) and matching tasks to individual employees (assignment) are both well-known scientific problems in Operations Research. Planning project execution via scheduling and resource assignment is claimed by [4] to be "core research content" in project management. Resources are typically considered to be the main feature of any project and therefore the Resource Constrained Project Scheduling Problem (RCPSP) is the basic and classic problem in project scheduling. [15] assessed various types of project scheduling and resources in their survey; e.g. multi-skill and heterogenous resources, which allow resource flexibility in allocation. For [16], resource flexibility in terms of skill-related constraints is of interest, too, when the authors introduce in their review of personnel scheduling three skills categories: user-definable, hierarchical workforce and specific skills. Further, the authors focus on "workforce planning incorporating skills" [17] to provide operations researchers with a combination of technical and managerial knowledge in order to encourage them to produce more realistic solution approaches. The Multi-Mode RCPSP (MM-RCPSP) is a generalization [18] or an extension of the RCPSP [19]–[21] with multiple possible modes of execution. The Multi-skill Project Scheduling Problem (MSPSP) is an extension of the MM-RCPSP, where a mode corresponds to a feasible staff members' subset [20], and the multi-skilled RCPSP (MS-RCPSP) is considered an extension of a classical RCPSP where each resource may have a set of functions or skills to perform [19], [22]. This multi-skill feature of the problem is highly relevant for the project management domain, particularly, when it comes to assigning multi-skilled resources (teams) to different projects [19], [22], [23].

Skill-based Approaches simplify the influence of competences by introducing skills as independent, quantifiable variables. These are the qualifications required to serve a customer

[24]. When teams need to be composed [25], [26], hierarchical skill levels are used which are summed into a skill matrix. A team with an appropriate skill level is then assigned to a task. A task lasts no longer than one day and teams are assembled only for that day. In their review of personnel scheduling, [16] analyse different types of decisions regarding tasks, groups, shift sequence, time and others. The authors discovered an insufficiently addressed topic in the existing literature since only few papers have covered the team perspective in personnel scheduling; they stress how “one seldom integrates all the decisions of the personnel scheduling problem, such as forecasting and adjusting the workload distribution, […], hiring/firing, training skills […]. This is one of the major areas of future research opportunities: joining all these decisions into one single personnel scheduling problem” [16]. [27] elaborate on optimisation techniques for scheduling which is then tested within an empirical study of a software project’s staffing. Nevertheless, the model has several drawbacks: work packages never overlap (no parallel or joint work), developers have only one “expertise competence” (no competence levels) based on which they form (stable)teams at the beginning of the project. [28] conclude in their research on human resource assignment in a multiple project environment that “[…] there is no golden rule of staffing in organizations with multiple projects and with multiple skills collaborators”. Several authors [29]–[32] focus on competence-based project selection (from portfolios). [29] developed a holistic competence-time-quality scheduling model for optimizing IT project portfolios. Their model considers criteria such as staff skill enhancement, development cycle time and product quality and incorporates the fact that the skill level of staff members increases through practice. [30] and [31] develop models for optimizing project portfolio selection considering increase and degradation of competences (learning and knowledge depreciation respectively). [32] introduce a multicriteria decision support system considering both current and future competence requirements during project portfolio selection. In [29]–[32], authors do not consider a team perspective and justify this decision by claiming that each task requires only a single skill or consider only individual levels of employees by claiming that the individual [competence] level of an employee is much more realistic than an aggregated team-based one [30]. Despite these papers [29]–[32] all being hinged upon the concept of "competence" that concept was not introduced at all but simple skills were used. Within the project scheduling and staffing domains, the dynamic nature of competences (e.g. learning effect) has been addressed by [33]–[35]. [33] define the cumulative average efficiency of a staff member, which improves after working more time on a given task. Meanwhile, [34] develop a model where some employees do not have a required skill but acquire the skill by working with a team member from whom the employee can learn it. [35] provide a recent review on scheduling problems which incorporate learning effects. The review only covers individual skills and not cumulative (team) skills or competences. Summing up skill-based approaches covered in the researched literature, one can conclude, that dynamic nature of competences including learning/forgetting effects form an emerging and worth investigating scientific problem.

Formal Descriptions of Competences, Operators for Adding and Subtracting: Competences are much more complex than single-valued skills or even skill vectors/matrices and therefore a major research topic in project management. Still, most research is based on textual, informal descriptions of competence profiles. Various quantitative and algebraic approaches towards competence management in general [9], [14], [36], [37] and within project and human resources management domains [13], [38]–[40] have been introduced. [13] highlight the advantageous role of competence quantification for competence management. They argue that competences must be evaluated via testing, performance measurement, or learning analytics. [14] propose using competence analytics and statistical assessment in a web-based platform. The authors apply a weighting system for three levels of competences which then ranks employees for certain jobs. [36] continue down this line of research and employ set theory to represent attributes related to the competence management methodology. An algebraic design of a competence management system should facilitate to the application of algorithmic solution methods, e.g. applied to calculating a competence gap or compiling a team competence profile. Currently, no scientific research in this direction with respect to the application in project staffing and scheduling problems has been conducted.

3.4 Problem Statement

Competence models are intensively researched and used, there is a huge variety of approaches and models. Verbal descriptions and competence/skills catalogues with verbal descriptions are common. Skills are rated on (quantified) scales. More complex formal models exist but are less common. Existing competence models do not sufficiently support digital processing and operations (e.g. plus or minus), making them unsuitable for data-based approaches.

3.5 Research Plan

A) Research Questions and Hypotheses

From the overall project goal, the following research questions are derived:

- What are the relevant competences for “Managing the Digital Transformation” (MDT)?
- And how can we reflect their dynamic change and their complexity?

The competence model for the digital transformation (CMDT) should be able to support the formulation of competence profiles which reflect the required complexity (e.g. the possibility to calculate a “plus” and a “minus”, data driven elaboration) on the one hand and reflect the change and development of competences (e.g. through learning) on the other hand. Therefore, the research is conducted in 2 scenarios leading to 2 generic conceptual models:

A1) Conceptual model and hypothesis with respect to the competence development

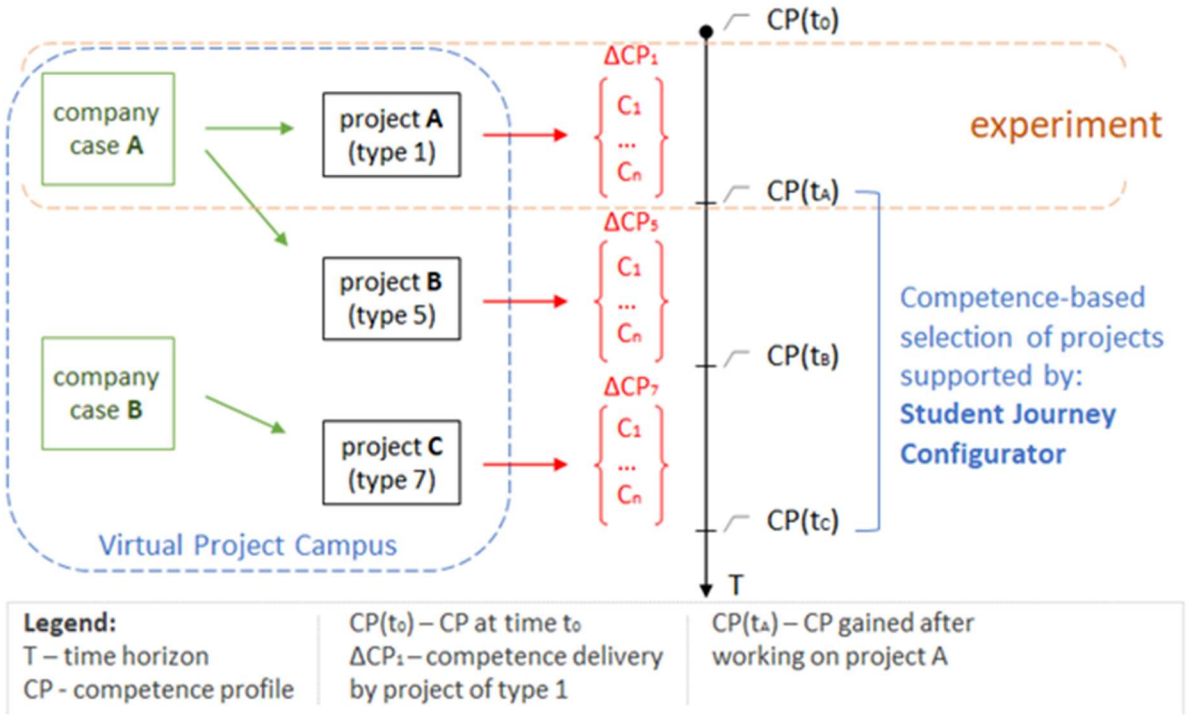

Figure 2: conceptual model for the competence-based learning with projects

For our conceptual model (see Fig. 2) we assume, that we have a pool of projects (A, B, C) which are linked to company cases (A, B). They are forming a “Virtual Project Campus” where teachers and students can select projects which they want to do. During their studies, we assume that students are conducting a sequence of student projects (see Fig. 2, project A, B, C) and that the projects are categorized by project type (see Fig. 2, type 1, 5, 7), e.g. as agile innovation projects, digital transformation projects, international team projects, customer-centric projects. Based on this, typical sets of competences are defined which are trained while doing such projects (and by conducting related educational activities, e.g. team trainings, intercultural trainings). The project types are connected with a certain set of soft factors which are typical for such projects. These soft factors define the soft skills which are needed and which are trained by the projects. The soft factors are derived from anticipated project situations (e.g. communication settings, potential conflicts) which are connected with the team roles and team situations which occur in such types of projects. In connection with the relevant technical competences, this forms the competence delivery (ΔCP) achieved by using the projects in PjBL settings. The accumulation of competences (see right part of Fig. 2) leads to the desired competence profile CP(t_n) of the graduates of the participating educational programmes.

A2) Conceptual model and hypothesis with respect to the project staffing and staff scheduling problems

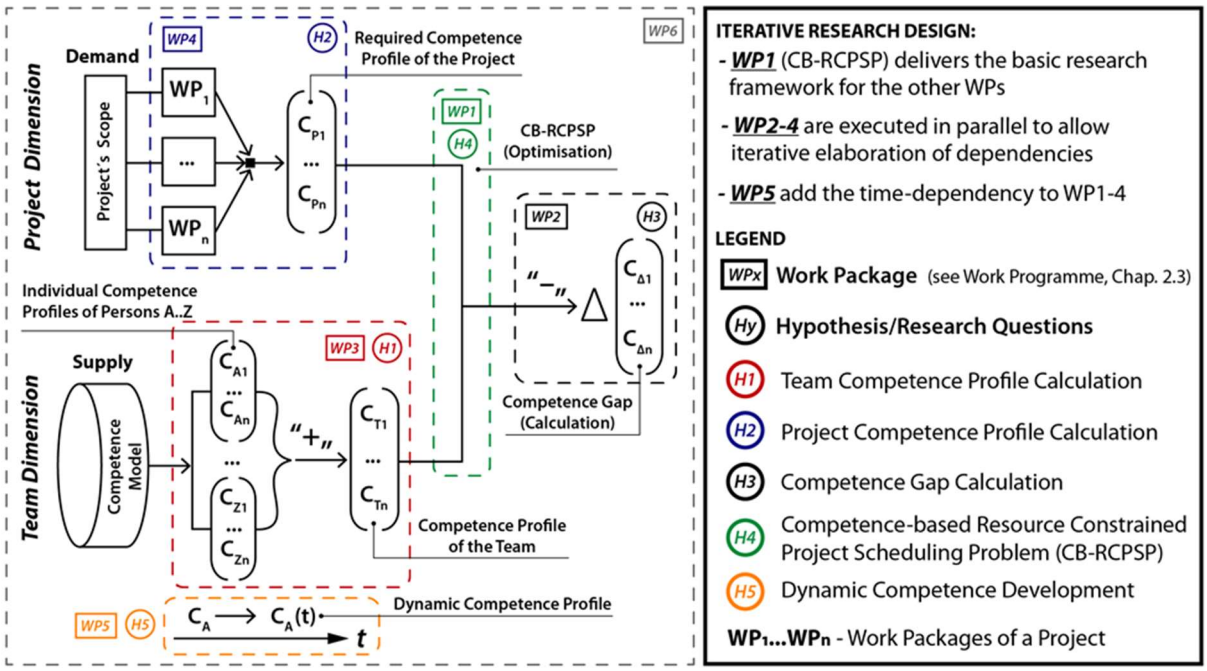

Figure 3: conceptual model for the competence-based staffing and scheduling of projects

In the basic version of the conceptual model (see Fig. 3) we consider a project staffing case where the team is already hired but not yet assigned to a specific project. The project's scope is already broken down into work packages (WP_1 … WP_n) and the required competences for each work package are known. We assume that each competence has an associated mathematical description. Furthermore, we assume that the individual competence profiles of team members are described by the competence vectors of person A: $\{C_{A1}…C_{An}\}$, …, person Z: $\{C_{Z1}...C_{Zn}\}$. *Hypothesis 1* claims that we can calculate the competence profile of the team $\{C_{T1}…C_{Tn}\}$ as a new and complex form of "sum (+)" of these individual competence profiles. *Hypothesis 2* claims that we can build a competence vector $\{C_{P1}…C_{Pn}\}$ from the competence requirements of a project's work packages: the required competence profile of the project. The main research question we want to answer is: which project team composition is best for completing the project? Due to the complexity of competence as a concept, a difference may exist between the required competence profile of the project and the competence profile of the team: the so-called competence gap. *Hypothesis 3* claims that the calculation of this gap represents a complex computational problem since competences are interrelated and it is not a simple "difference" which can be calculated by a subtraction of numbers. Based on an analysis of this gap, different team compositions may be considered, and, consequently, decision making based on this analysis will optimise the staffing and scheduling of the project. *Hypothesis 4* claims that there is an optimisation approach for the Competence-based Resource Constrained Project Scheduling Problem (CB-RCPSP) which leads to better project outcomes compared to other approaches. Finally, *hypothesis 5* assumes that the dynamic

evolution of competences during project runtime has a significant influence on the optimisation and needs to be considered. Part of this final hypothesis is the assumption that the time-dependency can be introduced into the mathematical model.

B) Research Methods

The following research methods are applied:

- Systematic Literature Reviews
- 8-step approach for conducting a systematic literature review adopted from (Okoli & Schabram, 2010)
- Delphi method
- (semi-) structured interviews
- Analysis of case studies
- Surveys
- Experiments

C) Research Plan

The draft version of the research plan foresees the following 3 work packages:

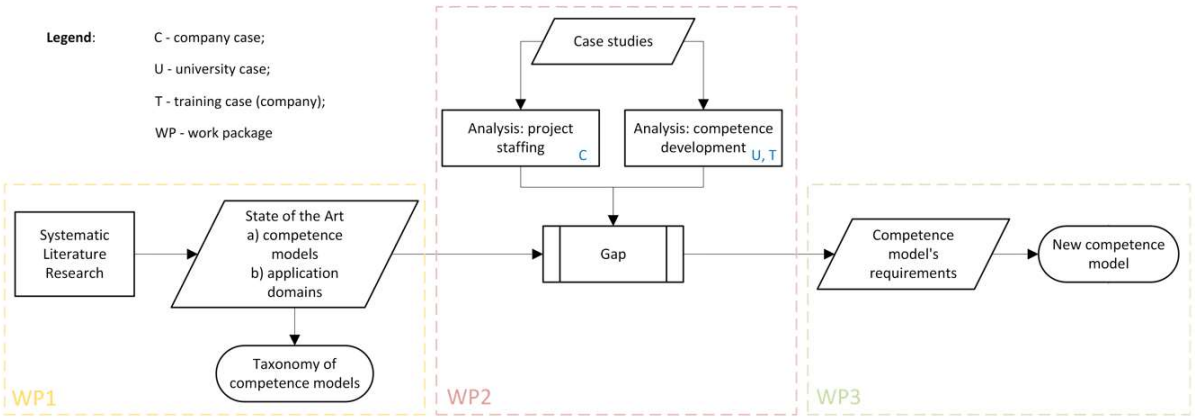

Figure 4: draft version of the research plan

3.6 Additional Considerations

t.b.d.

3.7 Dissemination & Standardisation

Results are planned to be disseminated and standardized with the IEEE and IPMA, e.g.:

- IEEE ETEMS conference series
- IPMA World Congress
- AIEPRO (IPMA) conference series

In addition, educational conferences and communities are addressed:

- ICL conference series

- SEFI conference series and special interest groups

3.8 Quality Assurance - Evaluation

Quality Assurance and Evaluation are done via the following mechanisms:

- Quality surveys among participants
- Review and release of results via Internal Evaluation Board (IEB)
- Publication in peer-reviewed conferences and journals
- Test in selected case studies

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