Outcome Specification:

Competence Model for the Digital Transformation (CMDT)

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

621745-EPP-1-2020-1-DE-EPPKA2-KA

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Version 3.0, 06.08.2024

Co-funded by the Erasmus+ Programme of the European Union

ProDiT
Projects for the Digital Transformation

1. Summary

Competences are a combination of knowledge, skills, abilities and attitudes which allow persons and 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 as well as 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 context of digital transformation. The goal of the research is to develop a digital model which will enable several operations in competence-based project staffing and competence development domains. These operations can include (but are not limited to): the calculations for composing teams (team dimension), deriving the required team competence from the project requirements (project dimension), calculating competence gaps and defining the competence development of the team over time within the digital transformation project.

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 required by a project or future, desired, competence profile,
- Planning the competence development of the individual or the team over time.

Current State-of-the-Art: Established and formulated problems only take simple competence definitions (quantified in skill areas and levels) for single staff members into account. However, the research on competences in project management indicates a more complex concept. In general, there are competence profiles of individual team members which cumulatively scale up to the competence profile of the team. Projects are associated with a required competence profile and the difference between team competence profiles and project competence profile is a competence gap which needs to be minimised. Adding to the complexity, competences can also change during a project's runtime (a dynamic aspect

which may be intended for team development) and competences are interrelated with other competences (they might amplify or inhibit each other). The research outlined will enhance existing project scheduling and staffing methods with a more complex competence-based approach. This requires research into formalised models for competence profiles which enables the “adding” and “subtracting” of competences. The dynamic behaviour of competences also needs to be respected. The result should provide a better match between people, teams and projects, leading to better project outcomes.

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. The proposed Competence Model for the Digital Transformation (CMDT) will enable several operations in competence-based project staffing and competence development domains. These operations can include (but are not limited to): the calculations for composing teams (team dimension), deriving the required team competence from the project requirements (project dimension), calculating competence gaps and defining the competence development of the team over time within the project.

Research Plan: The competence model will assume justification of several hypotheses:
H1: with CMDT we can calculate the competence profile of the team.
H2: with CMDT we can build a competence vector from the competence requirements of a project's work packages.
H3: calculation of the competence gap represents a complex computational problem, and CMDT can contribute to its solution.
H4: the dynamic evolution of competences during project runtime has a significant influence on the project outcomes and needs to be considered based on CMDT.

Next key research questions contribute to hypotheses testing:
- What are the relevant competences for “Managing the Digital Transformation” (MDT)?
- 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: CMDT validation will follow the Q methodology; release of results will follow via Internal Evaluation Board

Change History & Ownership:

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

Release V2.0: Next version of the specification of the CMDT, OpenCoP on Competences for the Digital Transformation, 21.12.2022

Release V3.0: Next version of the specification of the CMDT, OpenCoP on Competences for the Digital Transformation, 06.08.2024

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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

CMDT research covers two aspects regarding digital transformation challenges: on the one hand, competence management approaches require a digitally transformed way of handling competence data, on the other hand, this transformation can lead to a better management of digital transformation projects. 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-Skilled 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*, *staffing and scheduling*.

Competences for Engineers. For being competitive, "tomorrow's" graduates would need to demonstrate technical, professional and global competences [3]. This includes among others that those will need knowledge of project management as a part of "technical" competence. [4] bridge soft skills and project management skills by highlighting that engineers of the future would need not only technical but also soft skills, and they should understand project management, which could be reached by project-based learning.

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 [5]. According to [5], 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 [6]. 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 individual, team and, indeed, the entire organisation's competences [7].

Competences, Competence Profiles and Competence Models: The concept of competences is a very diverse research area with different approaches towards definition and modelling [8]–[14]. There is ongoing research on the differences between the terms “competence” and “competency”, as highlighted in [14]. [9] 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” [9]. 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 [5]). 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 [15]. [16] 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 formalism should be applied. [11] 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 [15], 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: 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 [6] to be “core research content” in project management. Resources are typically considered to be the main feature of any project. [17] 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 [18], 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” [19] to provide operations researchers with a combination of technical and managerial knowledge in order to encourage them to produce more realistic solution approaches.

Skill-based Approaches simplify the influence of competences by introducing skills as independent, quantifiable variables. These are the qualifications required to serve a customer [20]. When teams need to be composed [21], [22], 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, [18] 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” [18]. [23] 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 [24]–[27] focus on competence-based project selection (from portfolios). [24] developed a holistic competence-time-quality scheduling model for managing 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. [25] and [26] develop models for selecting portfolio of projects considering increase and degradation of competences (learning and knowledge depreciation respectively). [27] introduce a multicriteria decision support system considering both current and future competence requirements during project portfolio selection. In [24]–[27], 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 [25]. Despite these papers [24]–[27] 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 [28]–[30]. [28] define the cumulative average efficiency of a staff member, which improves after working more time on a given task. Meanwhile, [29] 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. [30] 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 [11], [16], [31], [32] and within project and human resources management domains [15], [33]–[35] have been introduced. [15] highlight the advantageous role of competence quantification for competence management. They argue that competences must be evaluated via testing, performance measurement, or learning analytics. [16] 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. [31] 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

In the reviewed literature sources skilled individuals are directly assigned to projects. Cooperation and team effects are not considered. However, project management research has demonstrated that the project team is not just the sum of the skilled resources.

Moreover, the reviewed literature reveals that the breakdown of the project into work packages is conducted via day/skill combinations which simply sum to the projects results. This is not realistic since adding up workdays does not in and of itself result in project success. With this approach, project integration effort is not considered, same as tasks/results which require cooperative work. In general, the approach of day/skill combinations is inadequate for the development of the required schedule and competence profile of a project.

Additionally, project staffing approaches consider just a static skill level or planned set of skills. Competence development resulting from undertaking projects or training, and the non-linear correlations between competences are not considered during assignment of engineers/engineering teams to projects.

Regarding the competence models, which 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. Such complexity is represented by interrelation of "Project-Person-Progress" concepts (see Fig. 2).

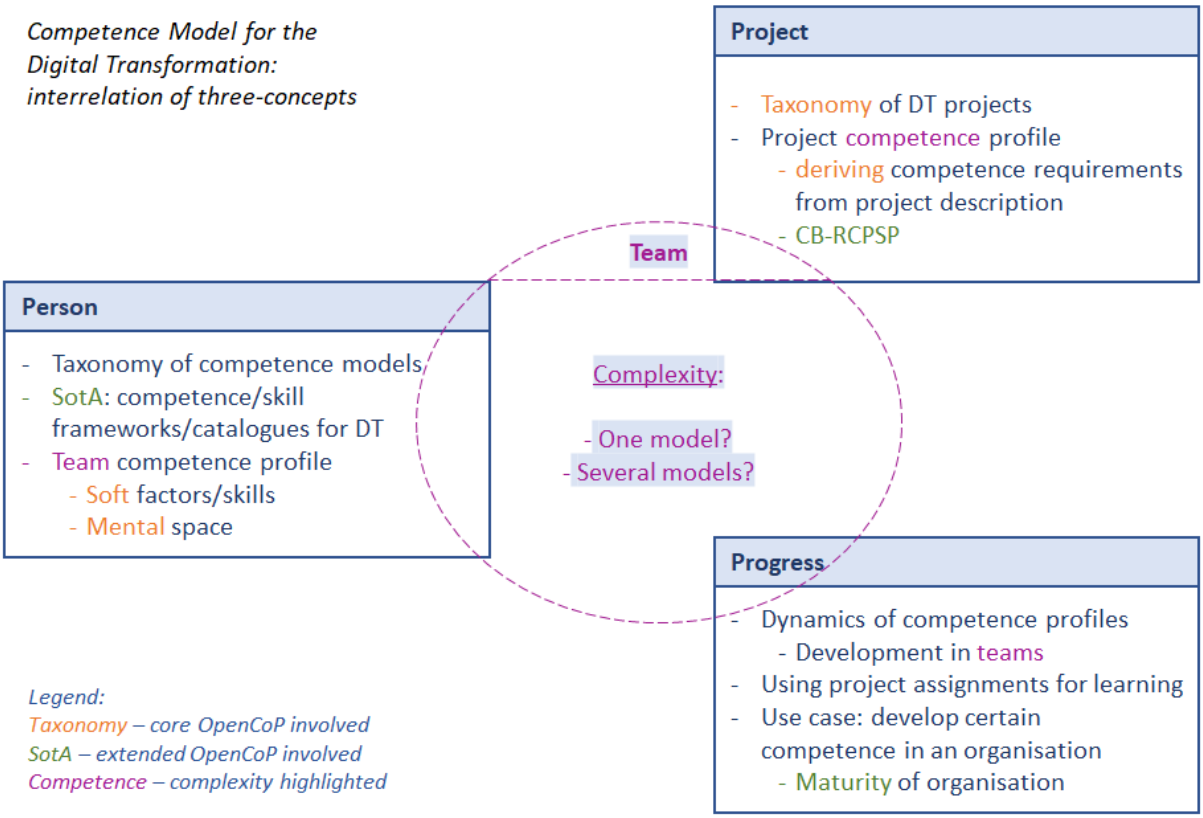

Figure 2 CMDT development: interrelation of "Project-Person-Progress" concepts

From the project perspective, not only the taxonomy of Digital Transformation projects is relevant, but also the complex, data-driven methods of deriving the competence requirements from project description. Such methods should contribute to the project competence composition, and in its turn, may contribute to the formulation of Competence-based Resource Constrained Project Scheduling Problem (CB-RCPSP).

From the person perspective, the taxonomy of competence models is highly relevant as it will show what are the description methods and the application domains of already existing

models. Further State-of-the-Art should contribute to a broader overview of competence frameworks specific for the Digital Transformation matters. The complexity in the person concept of CMDT is represented by the possibility to calculate a “plus” and a “minus” and data driven elaboration (see Fig. 4), which may be based on aggregation of soft skills of team members and aspects of a so-called “mental space” shared by the project team.

From the progress perspective, the dynamics of competence profiles should be explored to reflect the change and development of competences, e.g., through learning in teams (see Fig. 3). Since learning scenarios influence the overall development of organisation competence, this needs to be considered in frames of maturity and maturity models of organisation.

The “Project-Person-Progress” concepts are united in their complexities by the overall team perspective, as it should cover the interrelation of soft skills and factors in teams, which influence the development of a project team member, development of a considered organisation, and project outcomes. 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

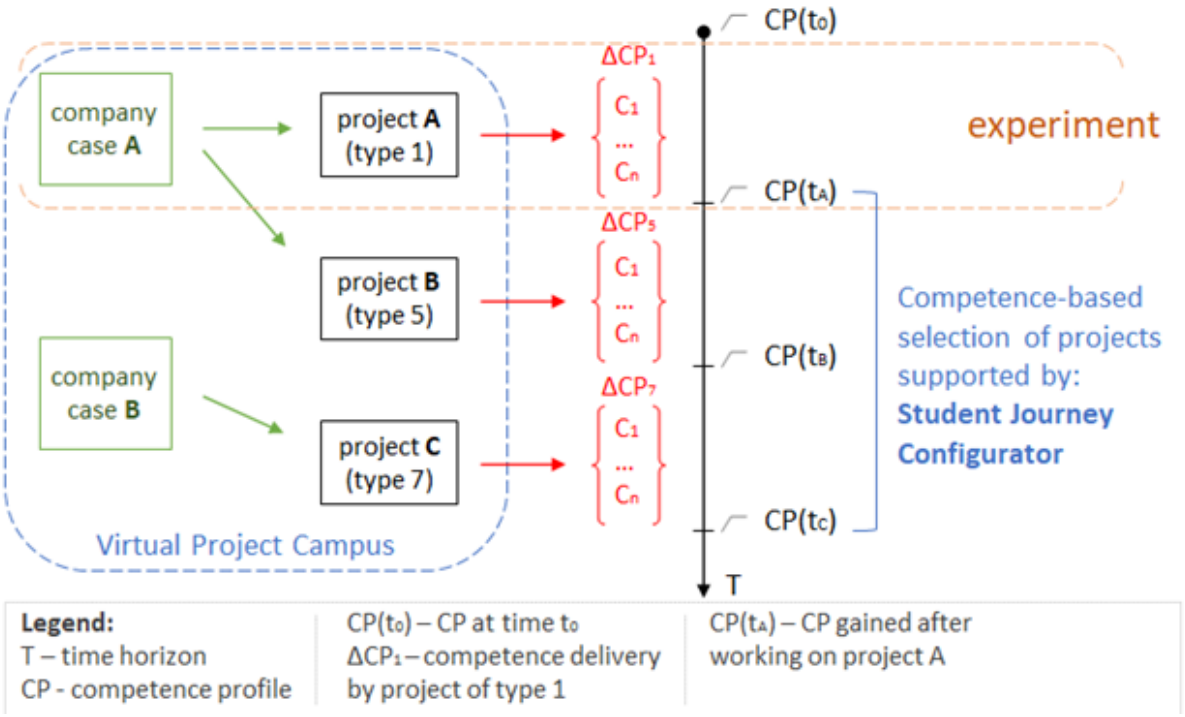

Figure 3 Conceptual model for the competence-based learning with projects

For our conceptual model (see Fig. 3) 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. 3, project A, B, C) and that the projects are categorized by project type (see Fig. 3, 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 relate to 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 relate to 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. 3) 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

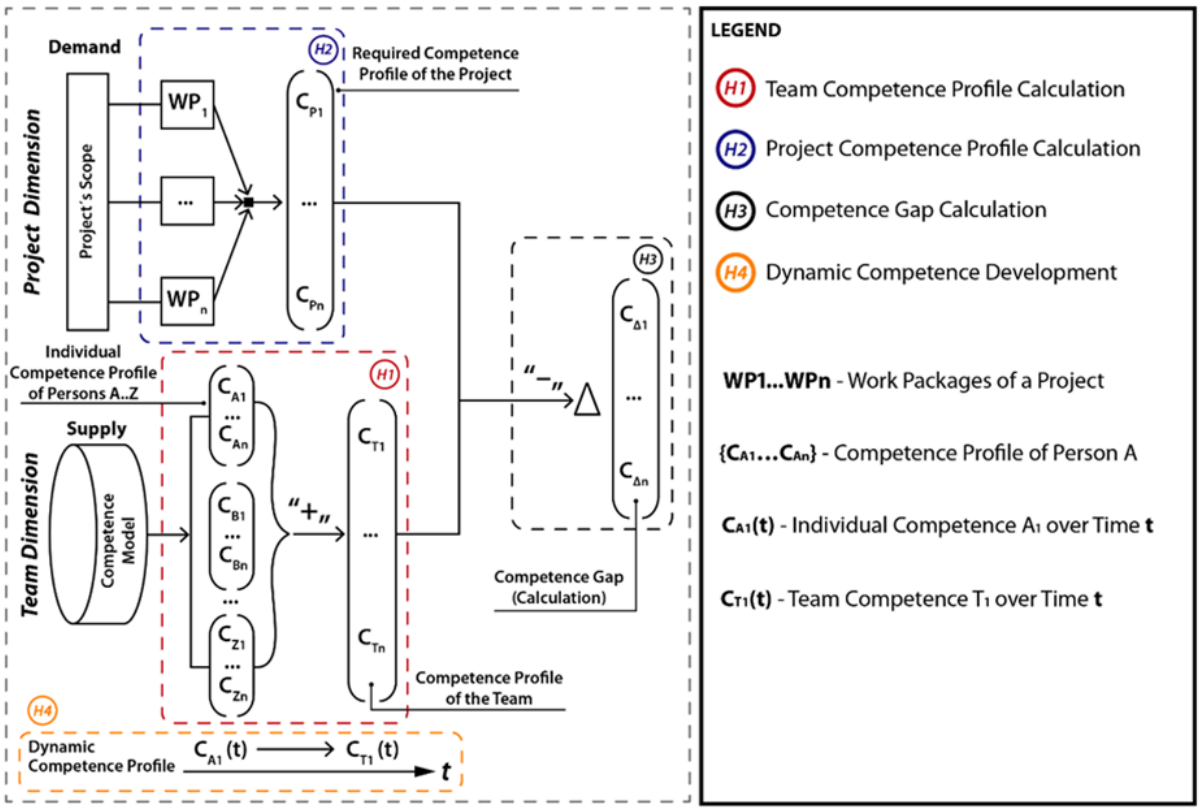

Figure 4 Conceptual model for the competence-based staffing and scheduling of projects

In the basic version of the conceptual model (see Fig. 4) 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; soft skills combination may lead to a balanced team, although, such combinations should be considered with caution regarding personality types of team members and possible issues of complementarity/overlap in soft skills. *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. 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 [31]. *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. Finally, *hypothesis 4* assumes that the dynamic evolution of competences during project runtime has a significant influence on the project outcomes, what needs to be considered. Part of this final hypothesis is the assumption that the time-dependency can be introduced into the competence model. In its turn, this requires (1) an in-depth analysis of teamwork and team dynamics and their predictability based on competences analysis, and (2) the combination of PjBL with competence-based staffing of projects. From both aspects, requirements towards the competence model can be derived with the focus on time-dependent changes of competences.

B) Research Methods

The main *research questions* intended to be investigated (for *H1-H4* see Fig. 4):

- how do soft skills of team members influence the team competence profile? (*H1*)
- which project team composition is best for completing the project? (*H2*)
- how will a developed competence model improve project staffing? (*H3*)
- how may a competence model be implemented to systematically deliver desired competences/competence levels considering the dynamic aspects of competences? (*H4*)

The next research plan (see Fig. 5) and following work plan are derived from a stepwise elaboration of potential applications of a competence model, and related hypotheses discussed above.

C) Research Plan

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

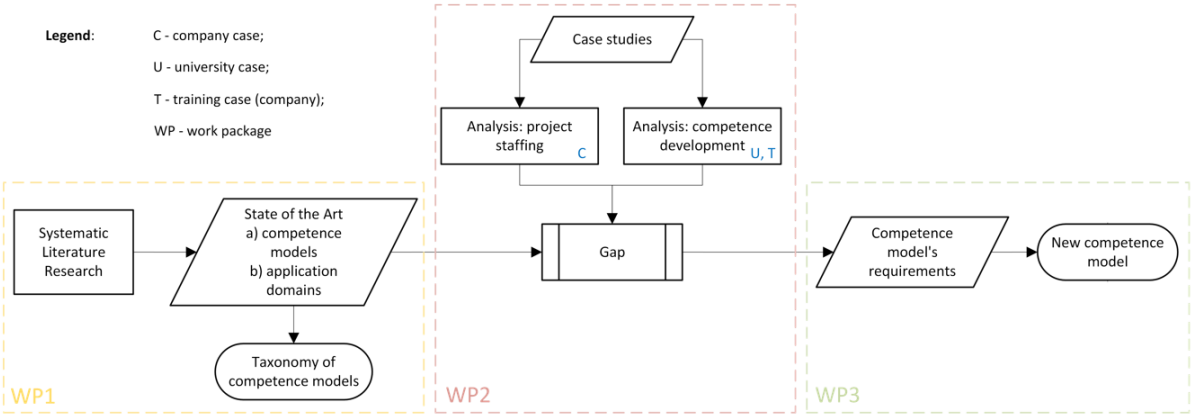

Figure 5 Research plan

Some tasks of this research plan will be iterated several times based on the assumption of static competence profiles. Only after developing a competence model under the assumption of static competences, we then investigate hypothesis 4 by introducing dynamic, time-dependent competences into the other three hypotheses. Research methods described below will support the investigation of the hypotheses.

C1) WP1: Develop Taxonomy of Competence Models

This WP develops a taxonomy of competence models based on the analysis of State-of-the-Art literature on competence models and their applications. This requires an in-depth analysis of existing in literature competence models, types of competence description, application domains, goals of such models and associated research problems and challenges.

Methodology:

- Alignment with PRISMA statement
- Conceptual structuring of the literature review
- State-of-the-Art review (literature for the last 5 years)
- Search strategy: systematic search and review
- Screening strategy: critical survey/review, data analysis based on empirical and theoretical literature
- Taxonomy (for conceptual classification of a competence model construct): integrative literature review

Supporting literature:

1. Grant, M.J., Booth, A.: A typology of reviews: An analysis of 14 review types and associated methodologies. Health Info. Libr. J. 26, 91–108 (2009). https://doi.org/10.1111/j.1471-1842.2009.00848.x.
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5. Robin, W., Kathleen, K.: The integrative review: updated methodology. J. Adv. Nurs. 52, 546–553 (2005).
6. Torraco, R.J.: Writing Integrative Literature Reviews: Guidelines and Examples. Hum. Resour. Dev. Rev. 4, 356–367 (2005). https://doi.org/10.1177/1534484305278283.

C2) WP 2: Derive the Gap in Existing Competence Models and Company Approaches

From one side, this WP analyses project staffing based on cases provided by engineering companies/projects. From another side, WP performs analysis of competence development in engineering companies and universities (engineering master programmes). These two types of analysis and literature research performed on a previous stage, will derive a research gap between existing competence models (in literature) and used approaches (in practice) towards project staffing and competence development.

Methodology:

- The methodology for interdisciplinary framework and systematic qualitative research methods like design science research (competence as an artifact) incl. case studies and surveys, will be followed
- Exploratory case studies analysis
- Gap identification based on surveying previous studies
- Data collection methods: qualitative, semi-structured interviews (with interview scripts and sample selection), critical incident technique, surveys
- Inductive data analysis methods: interview transcripts coding, template and thematic content analysis
- Meta-analysis after several cases, cross-case synthesis (organizing data according to the same pattern)
- Research report writing

Supporting literature:

7. Ciesielska, M., Jemielniak, D.: Qualitative methodologies in organization studies. (2017). https://doi.org/10.1007/978-3-319-65442-3.
8. Dresch, A., Pacheco Lacerda, D., Valle Antunes Jr., J.A.: Design Science Research: A Method for Science and Technology Advancement. Springer International Publishing Switzerland (2015). https://doi.org/10.1007/978-3-319-07374-3.
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10. Deb, D., Dey, R., Balas, V.E.: Engineering Research Methodology. A Practical Insight for Researchers. (2019).

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C3) WP3: Develop CMDT Based on Formulated Requirements

This WP develops CMDT by:

- analysing the requirements based on the previously derived gap
- developing a method for deriving the profile from project data (based on case studies' data)
- extending the competence model to accommodate the description of the required competence of a project,
- developing a method to calculate the gap between required competence profile and the competence profile of the available team,
- implementing a time-dependent dimension into the competence model,
- designing an approach for competence development planning in projects
- developing a calculation approach to take competence development into account

Methodology:

- Systematic literature review on competence development and learning in projects
- Semi-structured interviews with project leads on mismatches in project staffing
- Hard and soft modelling approaches
- Correlation analysis to analyse the effect of competence development on project performance
- Data preparation, developing a coding scheme for coding the individual and "project" competence profiles gathered from case studies
- Text mining applied to textual description of projects and competence profiles
- Employing basic heuristics while developing the model, and feeding the model with available anonymised competence profiles
- Confront the model with criteria of "Conceptual Goodness"
- Research report writing

Model validation methods following Q methodology:

- assessment of measurement validity (does the model generate the match?)
- assessment of internal validity (is the match valid and can be applied in practice?)
- and assessment of external validity (can the results of model application within a given set of competences be generalized to the larger set of profiles?)

Experimental evaluation method in form of simulation technique: testing the model with new project cases and new profiles to evaluate performance of the model.

Hard modelling techniques and analytical evaluation methods.

Qualitative interviews and survey to collect feedback after the model reviews.

Supporting literature:

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3.6 Additional Considerations

Research fields of competence development and competence management relate to complex scientific domains like psychology, cognition, social sciences and human resource management. The hypotheses listed above construct a new theory of processing competences. Therefore, the research requires a *mixed- methods approach* where deductive research expands the conceptual framework in operations research and competence management, while inductive research generates the connecting theory between both areas. The research plan is based on *Design Science Research* [36], combining systematic literature reviews with the construction of innovative concepts based on case studies, experiments and simulations.

The *design cycle* under the design science paradigm comprises of five main steps: *awareness of the problem, suggestion, development, evaluation, and conclusion*. This research design presumes that during every cycle a single problem is solved. As noted in [36], between the development and evaluation step an experiment or demonstration based on a case study should be performed. While CMDT development, experiments and scenario simulations will be performed to verify and validate the conceptual models. The *system development research process* outlines this sequence: construct a conceptual framework → develop a system architecture → analyse and design the system → build a prototype system → observe and evaluate the system. These steps are reflected in terms of iterative

repetitions of tasks, during which the competence model will be developed and refined. Interviews and expert reviews will be conducted to evaluate the results.

Special attention must be paid to the *systematic literature review* (as highlighted in [37]). Since the research deals with different scientific domains, the search strategy of the systematic literature review should be exploratory. In different scientific domains the topics might be researched within a conceptual framework which uses different concepts and terminology, therefore one should consider that different terms are used to represent the same concepts depending on the domain. The formulation of competences and cooperation effects does not yet exist, although, different scientific domains have studied these effects intensively. The scope of the scientific literature must be adjusted accordingly.

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, including the Q methodology approaches as highlighted in C3:

- 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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