Evolution of Competence Management in Manufacturing Industries

Markus Steinlechner[1], Fazel Ansari[1,2(✉)], and Sebastian Schlund[1,2]

[1] Fraunhofer Austria Research GmbH, 7, Theresianumgasse, 1040 Vienna, Austria
fazel.ansari@tuwien.ac.at

[2] TU Wien, Institute of Management Science, 27, Theresianumgasse, 1040 Vienna, Austria

Abstract. Manufacturing enterprises can identify organizational and human resource competence fields and individual competencies, which are documented. They mostly rely on technology management approaches to predict and supply future demanding competencies. Technology trends are examined and evaluated, and relevant competencies are derived. Others use data-driven trend analysis gaining benefits from internal and/or external data sources and expert opinions. However, a few manufacturing industries consider systematic selection and extensive use of competence-relevant sources and tools. Therefore, the planning and prognosis of future competencies remain inaccurate and incomplete. Although data-driven approaches majorly contribute to this area, the correct selection of data sources, objective assessment of causalities, and, thus, correct interpretation of findings are mostly unresolved challenges. A structured analysis of competence sources is carried out to contribute to the body of knowledge in competence management and provide a practice-oriented solution. External and internal competence sources are identified and combined in a targeted manner to compensate for the weaknesses of state-of-the-art approaches. In this paper, the initial results of the framework model are presented. A systematic literature analysis is conducted to identify possible competence sources. Target competence sources are described, and an initial classification is provided. As the main result, the classification of competence sources is transferred into a decision-support framework model for identifying future competence sources of workers in manufacturing companies. The developed framework model enables manufacturing enterprises to plan additional competence sources and relate them to job profiles on the shop floor level.

Keywords: Competence Management · Competence Profiling · Competence-Sources · Future Competencies · Framework Model

1 Introduction

In the era of digitalization and Industry 4.0, manufacturing enterprises have already recognized that employees, especially their competencies, are the most critical factor

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in successfully implementing digital transformation strategies [1]. Introducing digitalization and automation solutions cannot create sustainable benefits without considering employees' competencies. In other words, digital competencies can become the so-called "bottleneck" of digital transformation, and thus companies need to invest in innovative personal development and competence management strategies [2]. The scientific perspective supports these findings from practice. Research on the impact of digitalization and automation on business performance reveals the non-readiness of employees in dealing with digitalization solutions [3–5].

Industry pioneers start with identifying requirements created by emerging technology trends or digitized working steps and automated working environments. They try to link these requirements to the current competencies of their blue-collar workers, thus identifying gaps and developing training programs as counteract measures. Competence planning is centralized and is considered a strategic function. However, employees, especially blue-collar workers, are passive consumers of pre-defined qualification measures. Their qualifications, preferences, career development goals, and expectations are not individually concerned [6].

It is difficult to define which competencies will be needed for digital work in the future due to many influencing factors such as technology trends, guidelines issued by the European Union, corporate strategy, or the employees' perspective. Tangible and understood influencing factors are used to define the needed competence level of employees. Influencing factors recognized but not considered due to lack of opportunities or unrecognized influencing factors lead to single approaches defining the future competence level. For example, a single approach arises when companies ask employees about their future competencies and exclude upcoming technology trends because it is unclear how to derive competencies from them. The focus is on the present (questionnaire) and future (technology trends). Influencing factors from the past, like documented maintenance activities, are not considered.

Questionnaires and interviews [7, 8] defined future competence levels and focused on workers directly on the shopfloor or managers at various levels. Data-driven approaches [9, 10] only consider internal data sources like documented reports or work orders. External data stored in clouds and shared with customers and suppliers are unused. Part of the approaches to define the target competence level are based on a management perspective. HR, digitization, or process planning departments define competence levels. The remaining focus is on the shopfloor by asking workers or analyzing processes.

The question arises whether any combined approaches integrate the process and technology view. Furthermore, one-time determinations, e.g., by text mining on LinkedIn [11, 12] or through expert surveys [13], become less accurate over time. Mechanisms that keep the competence level up to date should be integrated. Focusing on single approaches and not considering other relevant influencing factors leads to an incomplete definition of future competencies, wrong competence development, rising costs, employee fluctuation, low resilience, and increased training and qualification time. The roll out of training measures across the entire target group, without considering if identified influencing factors vary between individual job profiles, amplifies these effects.

Based on these problems, the following hypothesis is derived: The more sources of competencies a company uses to define target competencies, the more accurate the target competency level will be, and fewer uncertainties will occur. This hypothesis leads to the following questions: Which competence sources can be used for which job profile? How can the competence sources be structured and depicted practically to enable companies to understand, select and evaluate relevant future competence sources for a job profile? How to evaluate the degree of improvement to which the incorporation of multiple sources of competency leads?

The questions and hypotheses that arose were summarized under the following main research objective: Development of a procedure to define a digital future competence level for technical specialists in manufacturing companies, considering all relevant competence sources to achieve a higher degree of accuracy.

This paper presents the first results of the desired solution. It is structured as follows: The first chapter presents the systematic literature analysis conducted to identify the sources of competencies and gives an overview of existing frameworks and approaches defining a future competence level. Chapter 3 contains the research approach and the procedure followed during development. In chapter 4, the competence sources are classified, and the classification is transferred into a decision-supporting framework model. The last chapter contains a critical reflection, conclusions, and future research steps.

2 Literature Review

The current literature is divided into three basic levels: First, the literature focuses on competence sources outside an enterprise, which serve as a basis for defining future competence levels. Second, literature considers the strategic level within an enterprise and uses relevant competence sources as the base. Third, literature that identifies competence sources at the operational level within the enterprise and uses them for the definition of employee's future competencies. In addition, there is a distinction between data-driven approaches, such as data-based competence planning using text mining, and non-data-driven approaches. Both span the three basic levels.

To examine the current literature status even more objectively, a systematic literature review has been conducted with rigor. The following scientific databases were used for literature research: Scopus, Web of Science, Springer Link, Taylor and Francis, and Emerald Insight. Literature research was also conducted in non-scientific databases, Google and Google Scholar. The period searched for literature was set from 2010–2022, focusing on literature from 2017 onwards. Initial search strings: competencies AND target state AND workforce. After screening potentially relevant publications online, 89 papers were downloaded. After further review and categorization into Gap Analysis, Special Method, and Competency Survey, 33 papers remained for detailed analysis. In the detailed analysis, the 33 papers were evaluated according to 14 criteria oriented to scientific, development, and application quality paradigms. Previous literature reviews [14] were used as a basis. All papers with a rating >10 are left for final analysis. Table 1 depicts examples of the ratings of the highest-ranked papers.

Gábor et al.'s (2018) work show that scientists' findings are mostly obtained through expert interviews and trends in past data, but no systematic approaches are used. With the Leontief model, which is applied to labor market data from the internet and thereby reveals the effects of technologies on the labor market and competence sets for workers in the automotive industry, Gábor et al. attempt to provide a systematic approach. It is intended to stimulate the redesign of future competence sets. The high rating that indicates to be closest to the research gap includes several perspectives, complexity, a high degree of self-development, transferable application, and the consideration of actuality. Weaknesses lie in the fact that it is only used in tests and that applications are not made available. The systematic approach has not derived competency sets from different sources on various levels and areas of levels. The approach moves only on one level and in one area of the level (outside the company-labor market data from the internet).

Table 1. Systematic literature review-evaluation.

Author and Year		Orientation	Perspective	Complexity	Sources
	0	Past	Employee	Questionnaire and Interviews	External
	1	Present	Enterprise	Data-driven approach	Internal
	2	Future	Industry		
Gábor et al. (2018) [15]		0	2	1	1
Deciusa et al. (2017) [16]		2	1	1	1
Vladova et al. (2019 [17]		2	1	0	0
Szabó et al. (2020) [18]		1	1	0	0
Li et al. (2020) [19]		0	0	1	0
Kusmin et al. (2018) [20]		1	1	1	0
Silva et al. (2017) [21]		2	2	1	1

Deciusa et al. (2017) have developed a management tool that supports small companies in conducting needs analyses of relevant personnel competencies. The basis is a guideline for personnel planning under technical innovations. The tool uses competence definitions from a strategic perspective and defines so-called competence anchors derived directly from the work activities. The assessment results from the high self-development and the connection of future and current elements. Weaknesses include the fact that only internal data sources are used, and no data-based approaches are included.

The developments did not include different approaches either. There was also no sufficient discussion of the different sources of competencies, their classification, and the comparison of their effects.

Across all other publications in Table 1, isolated attempts are being made to link approaches to achieve better definitions of future competence levels. To the best of the authors' knowledge, clear descriptions and evaluations of the used competence sources and their associated methods are unavailable. The topic of the improved definition of the competence level is in an experimental framework where a clear, over-arching approach is missing.

3 Research Methodology

First, well-known research methodologies in design science, such as Hevner [22] and Pfeffer [23], were analyzed to develop artifacts and models. Peffers et al. implicitly build on the framework of Hevner et al. and develop a six-step sequential process. This process is used as the basis for the defined research methodology in this paper. The research methodology is based on design science and aims to combine practical and scientific elements see Fig. 1.

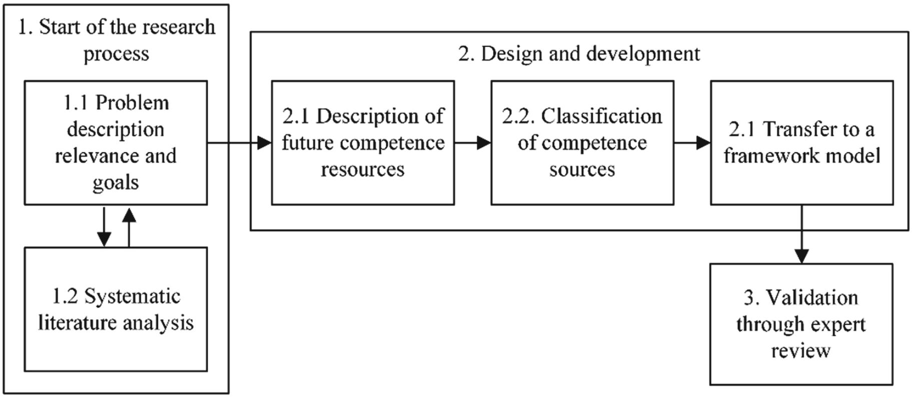

Fig. 1. Three-stage research methodology.

Step 1 – Start of the research process: This initial step is divided into two sub-steps. In the first sub-step, Problem description, relevance, and goals, the first rough descriptions of possible research gaps and problems were made based on state-of-the-art and project-specific databases. The descriptions led to the objective of taking a multi-perspective look at the sources of the target competence levels of employees in manufacturing companies and investigating them more closely. Based on the initial descriptions, a state-of-the-art analysis was carried out. With the result of this analysis, findings from implemented projects, and semi-structured interviews with experts from the projects, a systematic literature research, step 1.2, was launched. It serves as a deepening and focuses on specific methods of target competence definition and their application areas. In an interplay between new findings from the systematic literature analysis and the step-by-step refinement of the problem description, the research gap and the goals of the intended project were finally identified and set.

Step 2 – Design and Development: The second step contains the main steps for developing the framework model and is divided into three sub-steps.

2.1 Description of future competence sources: Identified future competence sources were listed. Data such as author, title, year, a short content description, the methodological approach, and used tools were added.

2.2 Classification of competence sources: The listed future competence sources were analyzed and classified according to their primary method. Using an iterative approach and concept mapping, all competence sources of each classification were analyzed in parallel, and cross-sectional functions were developed. The cross-sectional functions enable an in-depth analysis, support the comparison, and the finding of similarities.

2.3 Transfer to a framework model: The last step was to transfer the developments into a decision-support framework model. The applicability and feasibility of different representation models understood and used practically by responsible persons in the enterprise were evaluated. The final framework model was developed after discussions with experts with a high level of consulting and project experience in the industry.

Step 3 – Evaluation through expert review: The resulting framework model will be presented to experts from science and companies in an interview and evaluated based on predefined criteria. The aim is to increase the content's comprehensibility and the framework model's applicability.

4 Results and Discussion

The examined papers identified the following methods for defining future competencies (Table 2).

For the initial structuring, all papers using the same methods to define the target competencies were considered together. Cross-cutting functions were defined after several adaption cycles. On these cross-sectional functions, elements in the form of white boxes were placed, which included the headings of the papers' contents. The connections between the elements on the cross-cutting functions were depicted as a hierarchic structure. Figure 2 depicts the cross-cutting functions added for the method Technology (Method, data source, adaptation, model, results), the elements, and the connections between the elements.

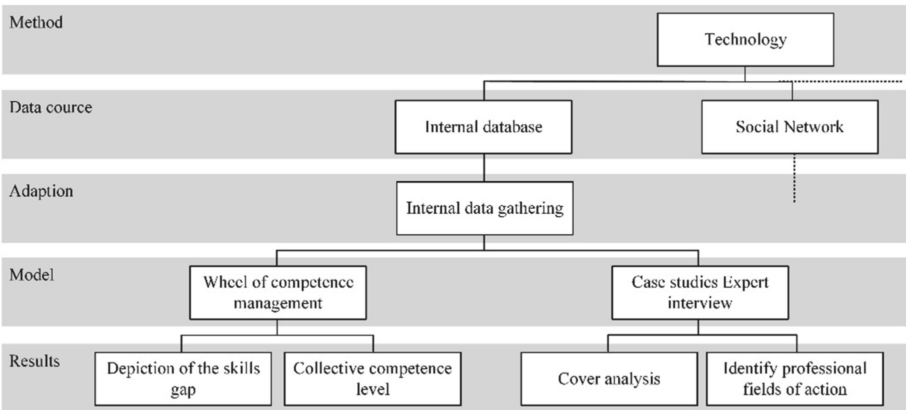

Fig. 2. Extract of structuring according to the method technology.

Table 2. Identified methods for defining future competencies.

Method	Description	Tool
Technology trend	Evaluation of upcoming technological trends and developments by employees and managers of the enterprise concerning relevance. Derivation of competencies from relevant trends	Questionnaire Workshops Interview
Industry trend	Examining industry trends and implementing interviews with industry experts to establish a set of future competencies for job profiles	Research Interview
Benchmark	Identify market leaders in a sector and define future competencies for employees by analyzing the activities and the use of technology	Research
Competence database	Research in available databases such as the ESCO or O-Net database for future competencies. Usage of the results for the future competence level	Research, Excel-based evaluation templates
Job profiles advertised	Examination of job advertisements on various job platforms regarding required competencies. Creation of a set of future competencies based on findings	Data-processing Data-Mining
Corporate strategy	Definition of the importance of upcoming technological developments for the enterprise by managers with insight into the strategic development. Derivation of future competencies from relevant technological developments	Excel-tools Questionnaire Workshops Interview
Training measures	Analysis of existing training measures regarding future competencies. Depiction of future competencies for job profiles based on the analysis	Excel-based tools Workshops

(*continued*)

Table 2. (*continued*)

Method	Description	Tool
Employees knowledge	Definition of the future competence level by interviewing employees	Questionnaire Interview
Internal job profiles	Specify future competencies by analyzing job descriptions available in the enterprise or job descriptions from public databases	Process-activity analysis Text-Mining
Activities analysis	Recording of activities carried out and abstraction of necessary competencies. Defining future competencies out of abstracted competencies	MTM, Observation, process descriptions
Digital tracks	Tracking of digital traces left by a user while using software (e.g., Word, MS Teams, ERP) Usage of the results for the future competence level	Special soft-ware Text-Mining

With the support of cross-cutting functions, concept mapping, and the hierarchic structure, it was possible to represent interrelationships between the papers. Furthermore, a basis for a generic use case for each method, which enables further developments in subsequent considerations, was created. However, considerations were made about how an applicable and comprehensible decision-support framework for identifying future competence sources might look. The result is a value stream representation supplemented with personas in a hierarchical structure and parts of organizational departments, cf. Figure 3. Organizational departments such as IT, administration, controlling, research, and development have been omitted because no identified method can be directly assigned. The identified methods are depictured on the value stream in the correct area. For example, the activity analysis method is placed right to the process modules. The corporate strategy method is placed by the management board.

The created framework model provides a good overview of the methods currently used to define future competencies in manufacturing companies. The following aspects are important for a correct interpretation: Not all necessary organizational departments are mapped in the framework model. Enterprises should insert their own organizational structure to see which areas are not yet used to define target competence sources. With this extension, maybe new future competence sources can be identified. The same applies to the value stream representation [24]. It represents only one possible structure of an enterprise. The process blocks and connections should be adapted to the actual conditions.

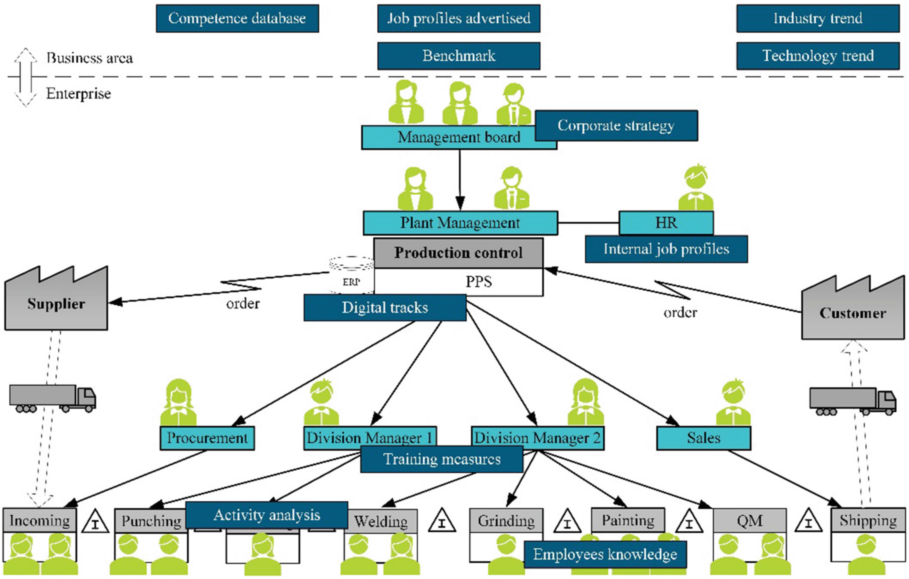

Fig. 3. Framework model for future competencies.

Theoretically, a method can be assigned to other areas within the framework. This cross-application to other domains may lead to challenges in the application, but it could provide further opportunities for defining future competencies. Through an adaptation to the current organizational structure and the value stream, additional job profiles or process blocks will be added to the representation. Specific job profiles or groups of job profiles and process blocks could be competence sources that have not been considered yet. Some methods have only been applied at a high level. A subdivision into smaller portions on different levels within an area is possible and may lead to different findings than in a high-level generic perspective. For example, the method of employee knowledge could be differentiated from a general survey that is the same for all employees to different ones for different groups of employees or departments. In the company's business area, methods are available which consider content outside the enterprise and derive content for the future competence level inside the enterprise. There may be more methods, but they are not yet known.

5 Conclusions

The framework model has been developed specifically for manufacturing companies and serves as a decision-support framework for identifying future competence sources. With the developed model, it is possible to get an overview of currently used future competence sources and their methods for defining future competencies. A company can quickly place itself in the context of the model and analyze which future competence sources are available, which ones have already been used by the enterprise, and which ones have not. Short descriptions of the methods and tools in Table 2 can be compared to the methods and tools used by the enterprise for defining future competencies. It is up to the enterprises i) whether they use the framework model as an overview and use some of the mentioned methods in initial or further projects or ii) whether they use the framework model to uncover further target competence sources.

The next step is finalizing the evaluation for applicability and comprehensibility through structured expert interviews. This step has been considered for future work.

The scientific contribution of this work is the first in-depth analysis of currently used future competence sources, their comparison and structuring, and presentation in a comprehensible depiction. Limitations occur in the following manner: The model can only be used at a generic level. A detailed breakdown would make the assignment of the competence sources inaccurate, and enterprises would have difficulties placing them in the context of the model.

Objectives for future research from a practical perspective are examining unused areas in the framework model to identify further competence sources. In areas such as supplier and customer, additional usable future competency sources may be found to improve the competency levels' accuracy. In addition, further value stream representations and organizational structures are examined to uncover further future competence sources. To verify the initially formulated hypothesis, key figures will be defined to evaluate the contribution of the individual future competence sources to the overall contribution. Once the key figures have been compiled, and initial findings have been obtained, it is planned to develop a practically applicable procedure model which enables companies to select and combine future competency sources based on key figures and define future competency levels with high accuracy.

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