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Development of a Procedure Model for Human-Centered Industry 4.0 Projects

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Abstract

The digitization of industrial value chain, so-called "Industry 4.0", is one of the most important economic and social development in the last years. It allows the high-wage countries, for example Germany, to maintain their business responsiveness and competitiveness. While research and development units are organizationally, personally and methodically aligned for innovation projects development, the development and introduction of innovations in a manufacturing environment face a great challenge. The process is often unstructured and has an unclear target. Especially the procedure to introduce human-centered Industry 4.0 applications focuses not only on a technical side of the question. To solve this problem, a socio-technical approach should be taken under consideration. Furthermore, employees have to be involved in the design and implementation phase. This paper presents a new approach to establish a method to introduce human-centered cyber-physical use-cases to manufacturing. After the definition of procedure models, successful and less successful projects are analyzed. This is the base to define requirements for this presented approach. Therefore a modular innovation framework is developed, which includes a systematic procedure with project phases, results of each phase, a toolkit with methods and checklists. Additionally, work functions and role models are examined. Special emphasis is given to employee work engagement. At last, the usability of this procedure is discussed.

Keywords: Industry 4.0; Procedure model, Project management

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1. Introduction

The digitization of industrial value-added processes, the so-called "industry"4.0" or "digital transformation" is one of the most significant economic and social developments in recent years [1]. Based on embedded cyber-physical systems (CPS) the digital transformation makes a new paths in human-machine-interaction. Embedded systems connect miniaturized processors with sensors and actuators and thus merge to form one cyber-mechatronic system. This is able to obtain information from the environment and to cause of feedback via actuators. [2] The performance of the embedded processors is not as good as the performance of the miniaturization restricted. The approach of CPS therefore goes one-step further and outsources its intelligence to external services. Limitations in the computing power can be compassed this way. In this context, it is important to underline that a CPS itself does not offer any significant benefit. The actual added value only comes from a highly integrated human-machine interface and a powerful service platform [3]. Figure 1 illustrates this below. Humans act as both sensor and actuator and interacts via a human-machine interface with the CPS [4]. These "new" opportunities of man-machine-interaction in a production environment are going in with changing customer needs, such as a short delivery time or an ever-increasing demand for variety of variants. Such interactions have been already visible in the consumer world with tablets and smartphones.

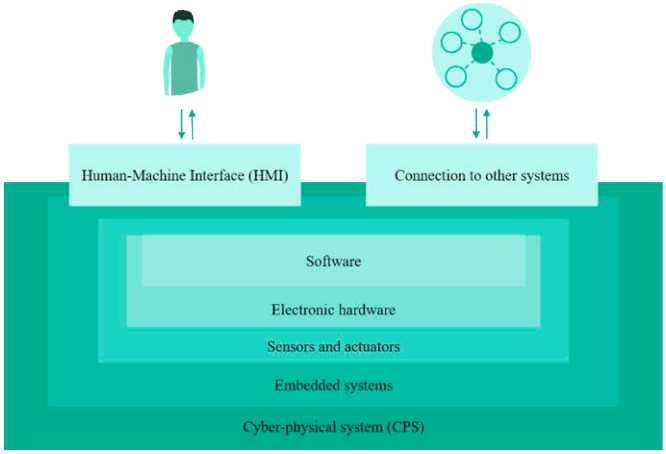

Fig. 1. Onion layer model of CPS [4]

In addition to these influences and the technical questions resulting from them the changing world of work, also known as the world of work 4.0, is a main challenge for politicians, companies and employees [5]. New requirements and job profiles of the employee or changing employment structures have disruptive potential and lead to changes of unprecedented speed [6]. Especially the change of the job profiles are characterized by a change in the required employee competencies. Abstracting and analytical skills can be mentioned as examples. Competences as well as knowledge of data processing and openness towards change. [3] This means that employees develop themselves proactively at their individual level. It also means the companies empower their employees to "to maximize the use of their abilities" in the future. [7] In the transformation process itself, the openness towards change outlined above is a central control lever. The aim is to activate and empower all stakeholders. This implies employees of all hierarchical levels, e.g. employees at the shopfloor, foremen or the management. Especially the qualification of the employees on the hall floor represents an important building block in the introduction of CPS and enables at the same time a demand-oriented qualification of employees [8].
For these new opportunities a procedure model is needed, which combines project management methods, change management and has the possibility to use classical or agile methods.

2. Industry 4.0 projects

The next chapter gives you a theoretical overview about projects, procedure models and reasons for project failures.

2.1 Procedure Models

For the introduction of human-centered industry 4.0 application cases on the a systematic approach is therefore necessary for the production shopfloor, which, among other things, takes into account the changed framework conditions and provides the parties concerned with offers a basic structure, flexible and demand-oriented the procedure for the respective project adaptively. For the implementation of the projects, a changed approach is necessary. Which is also determined by the influencing factors described, and which socio-technical system of people, technology and organization. The terms "project" and "process model" are described below in order to build on this, the approach of an approach model for human-centered industry 4.0 to be explained.

A project is clearly defined - as "a project that is essentially characterized by the uniqueness of the conditions as a whole" [10]. This DIN definition is often supplemented by the following premises and thus additionally concretized [11]: time limitation, uniqueness, interdisciplinary teamwork and processes based on division of labor and novelty.

Procedure models serve as a basic methodological framework and help to maintain an overview in the handling of complex action sequences in order to achieve a project objective [12]. Based on a problem-solving process "which describes a close relationship between objective, planning, implementation and control"[13], they present the chronological sequence of necessary activities, their responsibilities, methods and results for and thus serve as the basis for project management [14].

A project manager is a functional employee within a project management organization. In this role, he or she uses a specific project management methodology, which may differ from company to company. Part of this methodology is the process model that the project staff (and the project manager) can use [15]. Project management is for this reason not to be equated with a process model.

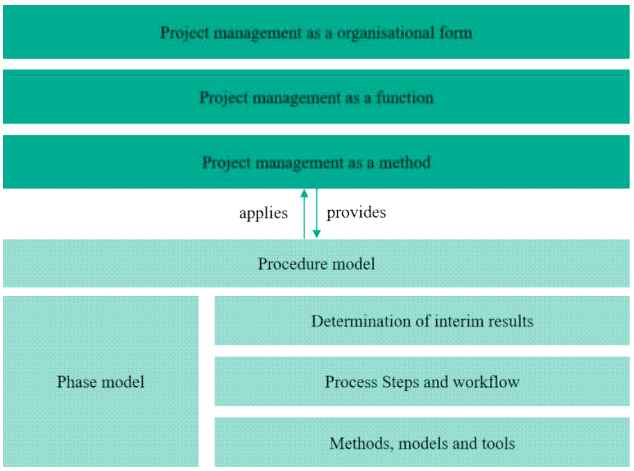

Fig. 2. Classification and relationship of procedure models and project management. [11], [14], [15]

Procedure models are used in projects for this purpose, the project manager as well as to provide project staff with guidelines for the implementation of the projects. The models are structured in such a way that there are defined project phases which are integrated into a temporal sequence in the phase model or process model. For each project phase, there are fixed intermediate results as well as freely selectable methods and tools as well as templates.

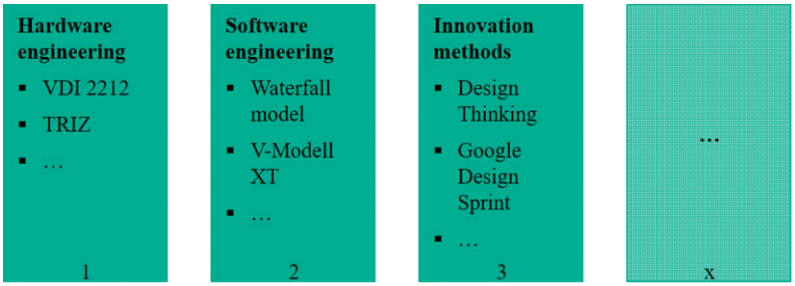

Fig. 3: Various product development disciplines and a selection of associated procedure models [16], [17], [18], [19], [20], [21]

According to the literature, there is a multitude of models, which, however, have been developed only for one specific discipline and are based on the passage of time have been optimized: exemplary are models for the hardware development, software development or modern innovation methods like a design thinking process or Google Design Sprint.

2.2 Reasons for project failures

As every art of the project is possible that Industry 4.0 projects also fail or have some difficulties. It is interesting to look after the causes or reasons for failures. Therefore a literature review was carried out. These helps us to get a closer look to understand and to avoid these mistakes in the future. Table 1 gives the overview about the issue.

Table 1. Overview of the most significant reasons for the failure of innovation projects.

Survey	Form	Study participants	Reasons for failure
Mercuri Urval 2012 [22]	Computer-assisted telephone interviews, Europe	1400	Low communication competence, little willingness to change, loss of productivity in day-to-day business during implementation
Müller-Stewens, Menz, Markus et al. 2014 [23]	quantitative, questionnaire, worldwide	160	Lack of support from top management, insufficiently defined objectives, missing milestones (no measurability)
Jorgensen, Bruehl und Franke 2014 [24]	Quantitative, questionnaire, worldwide	1390	Innovation-unfriendly corporate culture, insufficient resources (e.g. budget, employees), underestimation of complexity
Kuester, Reinartz und Schuhmacher 2015 [25]	Qualitative expert interviews, grounded theory analysis, unclear	29	Limited rationality in the decision-making process, innovation system and culture (e.g. in dealing with failure), micropolitics
Tagwerker-Sturm 2016 [26]	Quantitative, questionnaire, unclear	32	management mistakes, low importance of innovation, sluggish and slow internal processes
Koch 2017 [27]	Qualitative, treatise and analysis in the form of a novel, Germany	app. 25	"Change loop" - too much change, too often, lack of employee involvement → Over-rumbling, pessimistic attitude towards change

Summarized, the comparison of the studies clearly shows that the most frequent factors are due to deficits in the following areas:

- Insufficient change management
- Corporate culture that inhibits innovation
- Insufficient support and quality of decision-making by managers
- No/inadequately planned project features

2.4 Summary

In contrast to 'normal' projects, industry 4.0 projects are characterized by an unclear objective and/or an unclear solution. Innovation-supporting process models differ from established process models in that they provide phases, tools and roles that allow creativity to be systematized in a certain way in order to deal with this ambiguity. The information acquisition and identification phase required for this is lacking in the established process models from hardware and software engineering. In addition, there are other reasons why established process models are not equipped for the introduction of innovation projects. These reasons were gathered and discussed in some workshops:

- Industry 4.0 projects are increasingly becoming interdisciplinary projects that combine hardware and software requirements and can no longer be clearly separated from each other.
- The procedural models of software and hardware engineering are unsuitable for use with unclear objectives.
- Too high formalism: There is the danger that the focus shifts from the actual problem solution to compliance with formal requirements.
- High training effort in documentation and methodology; in some cases also missing provision of tools.
- Lack of focus on change management measures
- For hardware engineering procedure models: too little configurability, incomplete inclusion/consideration of the end user and low consideration of software (engineering) requirements in projects with hybrid character
- For software engineering procedure models: too abstract, very extensive. For example the documentation of the V-Modell XT version 2.1 includes e.g. 466 pages and is therefore not suitable for small projects

3 Procedure Model MyCPS

The process model developed in the MyCPS research project is divided into seven project phases. In each project phase there are intermediate results, functions and roles, methods, models and tools, as well as the special focus on the employee involvement. Combination of the individual elements in the process model is described in the matrix structure of project hares shown on the horizontal and the elements is shown on the vertical axis. A description of the individual components is described in the following chapters.

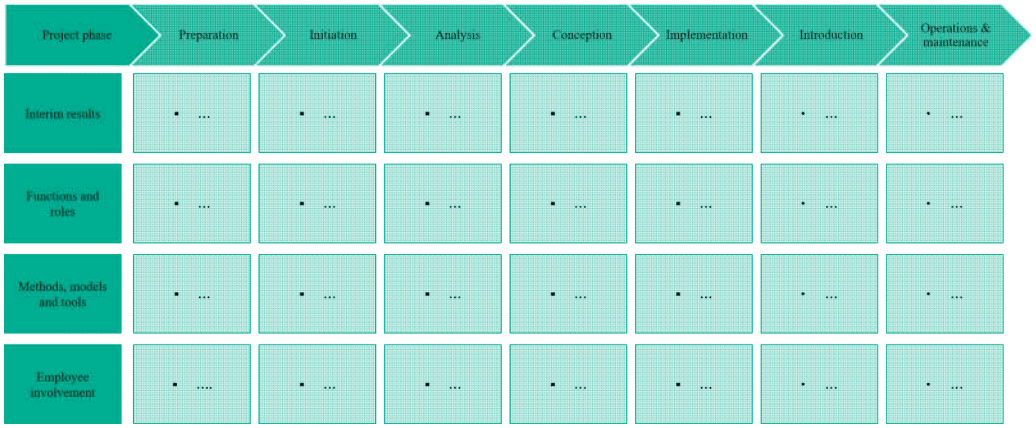

Fig. 4. Rough structure of the procedure model MyCPS

3.1 Phases in the procedure model

The project phases in the process model are defined as follows:

- Preparation phase: Clarification of the requirements and framework conditions for the project. If necessary, a preliminary investigation will be carried out. The project phase is scheduled to begin before the official kick-off of the project.
- Initiation phase: Determination of organizational structure and procedures Structures in the project. Definition of goals, work packages, responsibilities and deadlines.
- Analysis phase: recording, analysis and evaluation of the status quo.
- Conception phase: development and evaluation of solution approaches.
- Implementation phase: detailed planning of the prioritized solution and implementation.
- Introduction phase: integration of the solution into the operational processes. Step-by-step transfer of responsibility for process owner or the area manager.
- Operation and maintenance: operation phase with continuous improvement process (CIP)

Fig. 5. Project phase in procedure model MyCPS

3.2 People functions and roles in procedure model

Industry 4.0 projects require interdisciplinary project teams with different disciplines within the company. Project employees come from direct and indirect areas, and depending on the topic, the works council and, for example, the employees' representatives or the data protection officer must be involved.

Project phase	Preparation	Initiation	Analysis	Conception	Implementation	Introduction	Operations & maintenance
IT	Supporter and protector of standards, Alignment with IT strategy	Providing facts for trust and transparency	Analyze supplier market	Create transparent and secure IT architecture	IT architecture: Organize layer model and structures	Designing IT in a versatile way	Propose advanced concepts; CIP
External experts	Support in work package creation	Understand project description	Provide experience and knowledge from previous projects	Consult project team	Consult project team	Consult project team	Consult project team
Works council	Understanding opportunities and threats	Inform employees	Identification of possibilities for employee involvement	Identification of possibilities for employee involvement	Inform and support training	Offer ways to doubters	Check new target times. Creating operational status reports
Data protection officer	Define scope	Establish data security and data protection rules	Contributing experience and knowledge	Consult project team; review project results	Consult project team; review project results	Review project results	Review project results
Work safety	Understand project description	Gather information	Analyze work safety issues	Contribute experience from work safety to the concept	Checking compliance with work safety regulations	Gain knowledge from accidents at work and pursue improvements	Gain knowledge from accidents at work and pursue improvements

Fig. 6. Selected people functions and roles with relevant tasks in every project phase.

To carry out the projects, a special mindset of the employees is required, regardless of their function in the company. Roles such as an innovator or influencer should be consciously promoted so that a coherent innovation culture can be found in the project or in the company.

A selection of functions to be involved is shown in the figure above. It is important here that not every project phase, every function has a task in the project.

3.4 Methods, models and tools

In addition to the described project phases as well as potential roles and functions within the project, the methods, models and tools are an essential part of the procedure model. It should be ensured that a company has a large selection of standardized tools available per se, e.g. process maps, qualification matrix or value stream maps. This offers the advantage that, on the one hand, it is easy to access a standard selection can be accessed, on the other hand, new methods can be supplemented.

The selection of the respective methods in the project is traditionally carried out intuitively and experience-based by the experts. A large number of project characteristics can be identified for the selection, such as project content, degree of innovation, degree of difficulty or the qualification of the persons involved.

Industry 4.0 is a collective term for various topics related to the digitization of industrial value creation. Therefore, there is a multitude of different topics and tasks behind it. Due to this there is no a priori "best practice and best practice" for the implementation of the projects. Tool Collection". The decision to select a method is to be made exclusively to the respective problem.

In the following, some methods, models and tools are presented, which are partly through the research and development partners within the research project and to make it available to third parties via www.mycpstoolbox.de for the be made available.

Table 2. Selected Methods, Models and Tools.

Project phase	Methods, Models and tools	Name	Description
Preparation, initiation	Model	Readiness-Check 4.0	Assessing the status quo of a company in the categories of people, technology and organization with regard to industry 4.0 using an online self-assessment available at www.mycpstoolbox.de [28]
Implementation, introduction, operations and maintenance	Tool	Model company agreement	Tool for implementing an industry 4.0 applications
Conception, implementation	Tool	Checklist for hardware usability	Tools for assessing the usability of equipment
Conception, implementation	Tool	Checklist for software usability	Tools for assessing the usability of software
Analysis, conception	Method	Design Thinking	Structured approach to user-centered idea generation and problem solving in interdisciplinary teams
Analysis, conception	Method	Google Design Sprint	A design sprint is a time-limited, five-step process that uses design thinking.
all	Tool	Performance measurement system	List of quantitative and qualitative criteria for decision making
all	Tool	MOOC	Online courses for educational purposes without or with low access and admission restrictions

4. Conclusion

Industry 4.0 is an important development. For a successful and sustainable implementation of these new systems, new procedure models are required. One of these was developed in the research and development projected MyCPS, which was funded by the federal ministry of education and research in Germany.

The developed procedure model for human-centered industry 4.0 projects offers companies practicable support for the migration of CPS to the shop floor. The involvement of employees in the design and implementation of

applications is ensured by the integrated approach of participation as well as methods and tools. Important functions, such as the works council, security experts, data protection officers and, above all, employees in the value-added area can be included in the procedure in a needs-based and targeted manner. Due to the socio-technical approach of the approach, the contents are not limited exclusively to technical questions, as can be found in traditional process models. Thus, the procedure model for the project team in the company contains contents for the successful analysis, planning, implementation and evaluation of use cases for the company shop floor.

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More information about the research project is provided via the website http://www.mycpstoolbox.de. Please apologize, that the website is in German language.

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