

Developing Safety Cultures for Industry 4.0. New Challenges for Professional Communication

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Abstract – Industry 4.0 principles will rapidly change the industrial landscape especially regarding novel risks. Introducing Industry 4.0 successfully requires an adequate corporate safety culture. Professional communication provides suitable tools to foster and shape the transformational approaches to establish safety cultures in Industry 4.0. This paper presents the results of two interview studies focusing on requirements regarding the development of transformation approaches towards a safety culture 4.0. The results indicate various requirements regarding assumptions, values and artifacts which reveal several fields of action for communication professionals that depend on three phases of the safety-culture implementation: The development, establishment and maintenance of a safety culture 4.0.

Index Terms – Industry 4.0, industrial Digitalization safety culture, , professional communication.

INTRODUCTION

Industry 4.0 is the concept for the industrial digitalization of the future and will not only revolutionize the way in which work is carried out but also entail new types of risks [1,2]. The key element in establishing Industry 4.0 principles is the employee: Those affected by the transformation process need to be involved in decision-making processes and perceived risks need to be taken seriously. However, current transformation approaches focus mainly on technological and organizational aspects [3]. A broad new field for professional communicators is to develop employee-centered transformation approaches that aim at establishing a corporate safety culture for Industry 4.0 (safety culture 4.0). ‘Safety cultures’ comprise attitudes and behaviors towards safety aspects in organizations as part of the corporate culture. Guldenmund [4] distinguishes three layers in safety cultures: Assumptions, values and artifacts.

This paper presents a study from the research project SiTra4.0 which aims at developing a transformation approach for the establishment of a preventive and participatively acquired safety culture concept as a decisive success factor for the implementation of Industry 4.0 in small and medium enterprises (SME). The approach is to develop behavior-influencing means of communication and participation that allow SME to initiate a transformation of the corporate culture regarding aspects such as value structures, perceived safety or informal behavior.

This paper presents findings from two interview studies which focus on requirements of a safety culture 4.0 for SME. Three research questions are addressed:

- Which requirements regarding assumptions need to be considered in the development of transformation approaches towards a safety culture 4.0?
- Which requirements regarding values need to be considered in the development of transformation approaches towards a safety culture 4.0?
- Which requirements regarding artifacts need to be considered in the development of transformation approaches towards a safety culture 4.0?

The findings are discussed from the viewpoint of professional communication regarding the development, introduction and maintenance of a safety culture 4.0.

THEORETICAL BACKGROUND

I. Transformation approaches for industry 4.0

Management and organizational research address the question why organizations undergo constant change [5]. Change processes are needed to transform existing institutions in order to foster technological progress and to innovations [6, 7, 8, 9]. However, the effort to change is contrasting with the strong inertia of the organization [10]. A large body of theories addressing this challenge has been developed in the field of organizational change [11].

Approaches and concepts in this context are often interdisciplinary and range from the adaptation of theories of child development, evolution and chaos theory [5] to the derivation of future forms of organization based on existing science fiction literature [12]. Newer concepts are, for example, the phase model of the transformation lifecycle [13] or the model of dynamic equilibrium [14]. However, the existing methodological pluralism can essentially be considered as complementary to organizational research. A large number of publications on the topic of organizational change exists [15]. To describe concrete implementation strategies and concepts, figurative or metaphorical terms are often used [16].

Consequence of the transformation towards Industry 4.0 are novel challenges for occupational safety and health protection that especially hinder SME at economizing digitally. What is missing are transformation approaches that combine technological changes with forms of responsible self-organization by employees in the everyday professional life that consider the various degrees of ‘digital maturity’ in industrial domains.

II. Safety and safety culture in industry 4.0

Various publications examine threats emerging in Industry 4.0. Several risks are predicted to be consequence of the interconnection of systems and machines, the increasing use of digital systems or issues of managing vastly increasing amounts of digital data that needs to be integrated and analyzed in the industrial production process [17].

The transition towards Industry 4.0 will drastically change the way in which humans and machines collaborate [18] resulting in novel demands on how work is carried out in safe and secure ways [19].

‘Safety cultures’ comprise attitudes and behaviors towards safety aspects in organizations as part of the corporate culture [20]. Existing definitions conceptualize safety culture as ongoing social process between corporate actors ([4,21]) or as an attribute of companies that manifests differently ([22,23]).

Goldenmund [4] defines safety cultures as “those aspects of the organisational culture which will impact attitudes and behaviour related to increasing or decreasing risk” and manifest on three layers: the layer of basic assumptions (regarding the nature of reality and truth, of time, of space, of human nature, of human activity, of human relationships), the layer of espoused values/attitudes (regarding hardware, software, people/liveware, risks), and the layer of artifacts (observable behavior). The first layer represents a safety culture’s core for the influence on behavior: Basic assumptions are implicit and direct the behavior of employees - the results of such behavioral patterns become observable on layers one and two.

Safety cultures have been the object of numerous investigations. However, few studies examine whether

safety-culture concepts are adaptable in the transformation towards Industry 4.0.

II. The role of professional communication in the development of safety cultures 4.0

The implementation of Industry 4.0 principles presupposes efficient communication: Regarding technological aspects, industrial processes increasingly depend on internet-based communication technologies which foster exchange information [24]. Beyond the technological perspective, (digital) communication skills of employees become increasingly important – especially in small and medium-sized enterprises: “SMEs [...] place particular emphasis on process- and customer-oriented skills (e.g. the ability to coordinate work processes), as well as skills relating to infrastructure and organisation, for example social and communication skills.” [25]. Although communication competency is regarded as basic requirement for several job profiles in Industry 4.0 (e.g., manufacturing engineers, robot programmers and informatics specialists [26]), it is the role of communication professionals to facilitate corporate communications in transformation processes towards industrial digitalization [27]. Such efforts include communicative means which shape discourses related to the question how Industry 4.0 principles should be implemented [28]. In this context, particular attention needs to be paid to adequate risk communication including tasks such as the development of safety/security standards, terminology, documentation [29], and trainings [30]. Technical communicators thus can become a trusted source of risk-relevant information [32] and achieve lasting improvements in existing safety cultures [33].

METHOD

To identify requirements in the development of a safety culture 4.0, several studies were carried out in a metalworking company which is currently going through digital transformation processes, e.g.:

- large production machines are equipped and monitored with sensors,
- paper-based production processes (e.g., routing sheets) are restructured with the help of digital technologies (e.g., documentation systems on tablets),
- robots which support workers in routine tasks (cobots) are introduced in production processes,
- production processes are increasingly restructured to better satisfy demands of customers and include novel technologies in the production portfolio (e.g., e-mobility).

The studies used a combination of methods: participatory observation, document analysis, and interviews with employees. This paper focuses on selected

outcomes of two interview studies: The first study aimed at reconstructing a 'worker's journey' with methods of industrial process modelling to survey the current state of production chains. The second study aimed at reconstructing role-based value-added chains [34]. Both studies addressed the current state of safety and safety culture in the company as perceived by employees as well as requirements and barriers of these aspects in Industry 4.0.

Data collection: Interview guidelines for both studies were developed. The guideline for the first study contains four parts addressing the following topics: expertise and tasks of the interviewees, perceived information flows and perceived level of information, perceived problems (in the production chain, in their daily work, at the interfaces between steps of the production chain), willingness to contribute to a safety culture. 15 interviews were conducted with representatives from the departments involved in the process chain. The interviews took on average one hour and were audio recorded with the agreement of the interviewees. Interviewees were shown a flowchart of the process chain and asked to situate themselves and their tasks within the chart.

The guidelines for the second study comprise questions about the following topics: perception of Industry 4.0, perceived risks of Industry 4.0, requirements of a safety culture 4.0. In the study 25 employees from different departments were interviewed.

Data preparation: The audio files of both studies were transcribed and anonymized. The length of the interviews is 45 minutes on average.

Data analysis: The transcripts were annotated manually with regard to statements addressing requirements and barriers in the development of a safety culture 4.0. Identified statements were categorized with a predefined list of codes based on the layers 'basic assumptions', 'expressed values' and 'artifacts' of the safety-culture model proposed by [4].

RESULTS

I. Requirements regarding assumptions in the transformation towards a safety culture 4.0

The results indicate that concepts for a safety culture that are purely focused on aspects of occupational safety are insufficient for Industry 4.0. Rather, occupational safety is embedded in a complex conditional structure of socio-technical systems. From this perspective, assumptions regarding perceived safety, product safety, data protection, machine safety, or process reliability are of interest. Statements of the interviewees indicate that an in-house change of assumptions must be achieved in order to prepare companies for Industry 4.0. They propose a shared understanding of safety, the role model function of management and the self-perception of employees as key requirements for the development of a safety culture 4.0.

Shared understanding of safety: Industrial digitization evokes a variety of new risks, ranging from 'global impact for the entire enterprise' (e.g., denial of service attacks on large industrial machines) to 'impact on the individual employee' (e.g., stress due to information overload). A culture of safety 4.0 presupposes a shared understanding of safety that encompasses all aspects of day-to-day work (such as legal consequences, ergonomic aspects) and includes new threats posed by digitization. In the following citation, an employee gives an example of various aspects which need to be incorporated in a shared vision of safety/security 4.0:

Study2_I14: Spontaneously I remember the topic of data security, that I cannot connect a private laptop here or contaminate data with any private memory sticks or devices. On the other hand, the subject of occupational safety reminds me that, of course, one should behave dynamically in the office, even at an office workplace. You can hurt yourself quickly and hurt slowly. So cut with a knife or crooked for years and then injure yourself on the disc, which is then an extremely slow impact of postural damage and that may also be one of the long-term consequences of this job.

The role model function of the management: Statements of the interviewees indicate that the management has to take the role of setting a good example of how a safety culture 4.0 is supposed to be achieved; on the one hand in-house with regard to desired actions, on the other hand outside the company when it comes to how the company is perceived by outsiders and what values it represents. This applies in particular to the area of risks: Leaders must demonstrate the correct handling of risks on an ongoing basis and ensure that the values of the company regarding security 4.0 are visible to the outside world. The following citation summarizes this requirement:

Study2_I16: From the perspective of leadership, safety culture is a well-experienced and exemplary attitude to the value of corporate and occupational safety, visible both internal and external.

The implementation of a safety culture 4.0 requires the underlying assumption that safety/security strategies must be planned before transformation approaches are put into practice. Statements of the interviewees indicate that – especially in the case of smart machines – security measures cannot be implemented after the launch. Continuous efforts of the management are necessary to achieve a transformation which adheres to such security principles. The intended goal of the transformation processes has pursued with determination and persuasion. Concerns and resistances of the employees must be addressed by comprehensively and transparently informing

them about goals, advantages and above all risks of the transformation. In the following citation, an employee emphasizes these tasks of the management:

Study2_I1: Change is based on discipline, resilience and lifelong learning. In addition to empathy in the introduction the new values must be defended with discipline in the turbulent day to day business with changing calls for simplicity and speed. It is neither permissible nor imaginable to turn from the chosen path. The necessary resilience testifies, despite possible setbacks, the common vision of corporate democracy and leadership principles.

The self-perception of employees: Digitization leads to significant changes in the work life of employees. Such changes include new forms of work (e.g., time sharing, crowd working) that are time- and location-flexible. Statements of the interviewees indicate that under such changing conditions safety improvements should not be solely initiated by the management. The employees need to take on the role of an 'entrepreneur', who actively participates in the transformation to an Industry 4.0 and develops solutions for emerging safety and security problems. The assumption should be that safety 4.0 can only be achieved with innovations which are initiated 'bottom-up' by the employees. Employees should actively demand and accelerate such upheavals, while the management should foster and direct initiatives. as the next citation emphasizes. In the following citation, an employee describes different layers which need to be incorporated in assumptions towards the self-perception of employees:

Study2_I1: Safety culture should ideally be perceived as a fixed star or guiding culture for the future. Only in this way is it lived and developed day by day and secures uniqueness in a time of similar products and services. It thus covers the microcosm of company and department, as well as the macro view of social responsibility and neighborhood.

II. Requirements regarding values in the transformation towards a safety culture 4.0

The results indicate a variety of requirements for attitudes towards hardware, software, people and risks in the development of a safety culture 4.0.

Attitudes towards hardware: New technological developments, in addition to extensive knowledge of the potential uses and risks of digitally connected machines, also require a positive attitude towards technological changes: Instead of perceiving digitalization as a threat, transformation should be understood as a necessity to survive disruptive innovations. Gaining knowledge about new technologies increases the added value for the

company (higher production quality, lower error rate) as the following citation emphasizes:

Study2_I13: The jobs are not reduced, but the work content changes. This is great for most people. So far, there is no training as a machine operator. We work with unskilled workers, whom we then train. The better their knowledge, the higher their pay scale. The employees have an interest in continuing education and training. And we have the win-win situation because quality and output are expected to increase.

Monotonous tasks that burden employees and cause stress should be identified and performed by robots. Employees can thus focus on the important aspects of their work:

Study2_I16: we need the support of robots, because we will soon have to do more and more shaping of metal forms and for this task a cobot – a collaborative robot – would be great.

Attitudes towards software: Internal procedures, rules and regulations should address new risks. Especially with regard to digitization and Industry 4.0, companies often develop isolated solutions that cause security problems due to missing domain-wide standards. Such problems can be solved through a positive attitude towards mutual exchange between companies and learning from best practice examples or adaptation of existing solutions for new tasks:

Study2_I8: Digital data and related issues are very important and will also be fundamental to the future of manufacturing companies. As the lot sizes get smaller, we will have to become more flexible and adapt to it. We need a new type of industry in which companies mutually learn from each other.

At company level, the development of new (digitized) procedures and associated rules and security measures requires a rethinking in terms of consistency: Departmental boundaries must be overcome in favor of cross-departmental development, which involves all links in the value chain - from development through production to distribution.

Study2_I6: In our company, the worker does not know what the distributor or developer is doing. Changes are not really tangible either. A shared understanding of the whole production processes, the relationships between links of the chain and issues which can occur is crucial. If we could improve this aspect and make procedures clearer to the people, I would say that things would work better.

In this context, documentation must be understood as a preparation for future tasks. Adequate formats need to be chosen in order to make documentation applicable in daily routines:

Study2_I13: I say in times of Youtube - if you have any problem at home, just watch a Youtube video. We need something like that at work, simple videos which explain workarounds for problems and risks.

Attitudes towards people: The attitude of executives and employees towards employee empowerment in security matters must be positive. Only if employees can and want to engage in discussions about the risks of digitization, tailor-made measures can be developed that ensure process reliability and fault-free products:

Study2_I9: I believe that it is always good if the employees are involved creatively. This means that the team itself can say how they can improve their processes on the spot and help ensure that there is maximum safety in the process, so that what we produce is flawless.

Empowerment is thus the basis for a lived safety culture. Management needs to be mindful of employee suggestions - this requires appreciation, attention, and listening.

Attitudes towards risks: Statements of the interviewees indicate that risk-aware (informal) practices and (formal) procedures require profound knowledge of potential risks which may occur in production processes. Risk knowledge must always be state-of-the-art and include current technological developments and legislation. It must be a constant objective of all employees to inform themselves about new risks and to exchange views on safety/security improvements.

Study1_I5: Employees must be continuously trained always or be informed accordingly, which new forms of threats emerge. The hackers are not asleep either.

Such risks should be taken seriously. It is not sufficient to introduce pro forma measures against risks - attention must be paid to the quality of their implementation. Pro-active approaches presuppose the continuous reflection on possible (new) dangers with the aim to exclude dangers in the following work. Such thinking should not only refer to physical well-being, but also encompass digitized areas of one's own work as the following citation emphasizes:

Study2_I7: An important step is to consider within a project, are there any special risks that you might not immediately see over the normal approach? Which special features are there?

Statements of the interviewees indicate that it is necessary to examine safety/security improvements not only for single workplaces but to redesign risk-preventing means for whole production processes. In this context, horizontal (along positions of process chains) and vertical information flows (between the management and the employees) are named as key element in statements of the interviewees (see also [17]).

III. Requirements regarding artifacts in the transformation towards a safety culture 4.0

The results indicate a spectrum of requirements for artifacts to be considered in the development of a safety culture 4.0. Such requirements comprise safety measures on machines, digital safety measures and training for safety empowerment.

Safety measures on machines: The wearing of protective clothing is a necessary measure that is not sufficient for the safety of employees when operating machinery. In the case of non-compliant behavior or new threats, the machine must be designed so that no damage occurs. The perceived safety of a machine is increased by attaching visible safety measures. New challenges arise with digitally controlled and smart machines. When operating such machines, greater attention must be paid to ensuring that the functionality of the machines is displayed comprehensibly and clearly to the employee. If machines are equipped with sensors, employees can read the recorded data to make predictions about potential problems (e.g., overheating, premature wear, communication problems between the machine and connected digital systems). Employees require assistance in interpreting such data as the following citation emphasizes:

Study1_I7: It is of course a technology problem. If there is a program running, it is often all Greek to me and you have to first know what that means. No manual includes such information.

Digital safety measures: Statements of the interviewees indicate that they are not afraid of technological innovations in general. Perceived risks result from potential impacts of introducing new digital technologies in daily work routines as the following citation emphasizes:

Study1_I8: I am afraid that new systems could interfere with my tasks. My greatest fear is that I arrive here in the morning, that it has been changed and that nothing works. I do not think so much that the application itself is the problem, especially for those who may be a bit computer-minded.

To reduce negative effects on the work of employees, digital systems should be designed to exclude handling errors by digital protection mechanisms. Such means

should especially aim at preventing the loss of sensitive data:

Study2_I8: Your own sense of security needs to be supplemented by the computer system, with which you work. It should be implemented as transparently as necessary, but as protected to the outside world as possible. Of course, that's a challenge for which I have a lot of respect. And this topic, how to deal with the data of the customers, not to get leaked, what platform to use, how can we guarantee security - that's a big challenge.

At the same time, digital systems should be designed in such a way that people are not overloaded with information in their work. Statements of the interviewees indicate that protection mechanisms should reduce stress emerging from excessive task loads due to a high number of variants and fast innovation cycles.

Training for safety empowerment: If employees are expected to actively participate in decision-making processes for Industry 4.0 – especially with regard to safety/security issues –, they need the appropriate basic knowledge to be able to identify safety problems and find proactive solutions (safety empowerment). Constant trainings for safety empowerment must take into account the knowledge levels, tasks and goals of employees individually. Content must be prepared to be directly usable in everyday work contexts:

Study2_I7: Trainings must be carried out consistently and constantly. Especially in terms of security you cannot train enough. We do that. Especially with regard to asking oneself: How can safety be improved significantly?

The goal of safety empowerment trainings must not only be a sensitization to existing safety problems and measures, but also prepare employees to think about safety on their own. Statements of the interviewees indicate that only employee-centered lifelong learning in the area of security will enable companies to develop resilience to new risks of digitization. When designing training courses for safety empowerment, it is important for employees to understand the significance of this measure. It should not be perceived as an (annoying) obligation, but as an appreciation: The company wants to position itself for the future and relies on the help of its employees. Training should be consistent with this vision and express appreciation to the employee. The employee experiences appreciation especially when he feels taken seriously by the company. In the following quote, an interviewee points out that safety empowerment trainings have a higher perceived value when performed by a trainer:

Study2_I13: Important for digital security training would be to have one in front of you personally, as in school. I think it's good for the employees because it makes them feel taken seriously. That's the main advantage.

DISCUSSION

The transformation towards processes in which humans, machines and resources communicate in novel ways takes place in an environment that is subject to conventional occupational health and safety rules which do not reflect the change in practices of Industry 4.0 adequately (e.g., new interfaces, increasing complexity, new flexible forms of work). What is missing are digital transformation approaches towards Industry 4.0, which include a digital safety culture and take into account novel (perceived) risks. Communicative and interaction-related strategies and measures for the cross-departmental introduction of a safety culture 4.0 play an important role in this context.

Here communication professionals come to new task areas. Results on such areas of responsibility from the present study partly confirm the findings of the literature, but go beyond: Instead of individual tasks such as documentation and training, the development of a safety culture 4.0 requires value chain-accompanying and interlinking means, which enable employees to initiate and lead decision-making processes in safety matters. A digital safety culture must be developed and practiced participatively and use innovative forms of responsible self-organization in everyday professional life.

The results reveal several fields of action for communication professionals that depend on three phases of the safety-culture implementation: The development, establishment and maintenance of a safety culture 4.0.

Development phase: A change of underlying assumptions in a safety culture will only be achieved by a successful transformation of values and visible artifacts. Transformation efforts will not result in the desired outcomes if their necessity is not communicated to those affected by the changes, perceived risks are not addressed, and employees are not actively involved in the development phase. Regarding these three objectives, communication professionals can act as mediator between employee-initiated bottom-up and management-initiated top-down change processes. Tasks to be focused in this role include identifying potentials for optimization (e.g., areas of application for robots with the help of methods of industrial process modelling), uncovering perceived risks (by constantly analyzing feedback from employees on changes intended by the management), and developing adequate methods of employee empowerment (e.g., in design thinking workshops). In this way, an understanding of safety/security 4.0 is developed which is shared by the management and the employees.

Communication professionals can help to translate vague values into tangible recommendations for action (e.g., guidelines, task descriptions, terminology) and identify suitable formats to represent such recommendations (e.g., video tutorials). Existing guidelines and rules need to be contextualized by communication professionals with respect to the particular tasks, roles, and work environments of employees. As impacts on daily work routines are among the perceived risks of technological innovations, it is necessary to test the usability of digital systems and smart machines in advance to their introduction. Such usability tests should be combined with a risk analysis from the perspective of employees. Communication professionals can prepare and lead the tests, analyze and discuss the results with the development department.

Establishment phase: The introduction of measures to establish a safety culture 4.0 is the most critical point in the transformation process - missing acceptance on side of the employees can lead to a failure of all transformation attempts. Risks of industrial digitalization perceived by the employees need to be identified and addressed with adequate communicative formats. To achieve a 'lived' corporate safety culture, some employees need to be selected as promoters of risk-aware behavior. The selection and training process of such promoters needs to be accompanied by communication professionals. As the management needs to be a role model for the intended values and related behaviors, communication professionals are required to advise superiors. Furthermore, concerns and suggestions regarding changes intended by the management need to be gathered. Communication professionals should recommend adjustments in the change procedures if necessary.

Maintenance phase: Communication professionals need to take care that the newly established codes of conduct are kept up: They need to check constantly whether formal as well as informal communication practices meet safety regulations and guidelines and whether information flows need to be improved to maintain a high level of safety information. Furthermore, continuous monitoring for new (internal and external) risks is necessary to keep guidelines and trainings up to date (e.g., by use of text mining and topic tracking methods). Communications professionals need to ensure that employees are constantly involved in risk-related decision-making processes.

Notwithstanding the contribution of this research to the understanding of safety cultures for Industry 4.0, and its confirmation of previous findings, it has some limitations. The study presented in this paper only focused on one medium-sized company in the metalworking sector.

Further studies should investigate other companies of different sizes, digital maturity, and industrial domains. Value creation chains of other domains and related process chains, roles, tasks, and work contexts need to be investigated. Insights may be gained by examining role-specific value creation chains [34]. Furthermore, the qualitative results of the present study should be verified with quantitative studies.

CONCLUSION

The transition towards an Industry 4.0 requires a changing understanding of safety: The progressing industrial digitalization leads to novel risks that go beyond the traditional understanding of occupational safety and health protection. Such issues require new approaches for safety cultures that consider various requirements regarding safety/security-related assumptions, values and artifacts as identified in the present study. Communication professionals can be of considerable value in establishing safety cultures 4.0.

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