Christopher Marc Schlick · Sönke Duckwitz
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Advances in Ergonomic Design of Systems, Products and Processes

Proceedings of the Annual Meeting of GfA 2016

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Editorial

The rising level of digitalization of products, processes, and services and the interconnecting computer networks are the driving factors for the increasing complexity of work systems. However, digital networked systems are not only causes of increasing complexity but at the same time they also enable us to individualize the work processes and adopt the job to fit the worker through deliberate research activities. We are just beginning to explore the potential of these new technologies in order to incorporate them in the design and evaluation of work systems.

These proceedings include a selection of papers presented at the 62nd Annual Meeting of the German Human Factors and Ergonomics Society (Gesellschaft für Arbeitswissenschaft GfA), held at the Institute of Industrial Engineering and Ergonomics of RWTH Aachen University from March 2 to 4, 2016. The conference featured more than 200 presentations and 36 posters reflecting the diversity of subject matter in the field of ergonomics, human factors, and industrial engineering. The book provides a wide range of thematic areas and deals with aspects of complexity in the design of work systems, considers digitalization in the design of products, and takes role of networks in the design of processes into account.

The contributions in this book address research questions on the interindividual as well as on the individual level. The contributions at the interindividual level regard work processes within the overall context of society as well as issues at the organizational and team level. Furthermore, contributions on the individual level deal with the characteristics of work activities and technical fundamentals of workplace design.

Considering the wide range of topics covered and the variety of scientific methods applied, it is apparent that advances in the field of human factors and ergonomics may only be achieved by a multidisciplinary approach. Thus, these proceedings address human factors and safety specialists, industrial engineers, work and organizational psychologists, specialists in occupational medicine, as well as production planners and design engineers.

The contents of this edited volume required the dedicated effort of many people. We would like to thank the authors, whose research and development efforts are published here.

Aachen, Germany

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Contents

Best-Practice Approach for a Solution-Oriented Technology Assessment: Ethical, Legal, and Social Issues in the Context of Human-Robot Collaboration

Jochen Nelles, Susanne Kohns, Julia Spies, Christina Bröhl, Christopher Brandl, Alexander Mertens, and Christopher Marc Schlick

Abstract

Future robots will process work tasks with a high degree of complexity even for small batch sizes in collaboration with the working person, simultaneously, and within a specified workplace. Due to the transformation from robots that are spatially and temporally separated from the working person and are programmed to execute tasks in a deterministic manner towards collaborative, adaptive lightweight robots, ethical, legal, and social implications (ELSI) should be considered. The purpose of this contribution is to determine how changing human-robot collaboration impacts technology. To this end potential ELSI problems and their possible causes and effects are identified and quantitatively analyzed based on the Aachen Model of Identification, Classification and Analysis of ethical, legal, and social Implications (AMICAI). Furthermore, the impacts of technology are identified and evaluated alongside potential risks, opportunities, and potentials of human-robot collaboration. This best-practice approach describes the results of applying AMICAI based on expert workshops focusing on the application example of a human-robot collaborative workplace in manufacturing.

Keywords

Technology assessment • Ethical, legal, and social implications • ELSI • MEESTAR • AMICAI • Human-robot collaboration • Human-robot interaction • Workshop • Best-practice

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This article is an extended version of the first publication by Nelles et al. (2016)

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1 Introduction

Recent developments in the robotics industry lead away from robots as part of highly automated manufacturing facilities for large batch sizes, through to collaborative (light-weight) robots in individualized manufacturing processes. Previously robots were spatially and temporally separated from the working person. Robots under development now are placed in a collaboration area together with the working person. This collaboration area is an area in which the robot and the working person can perform manufacturing tasks simultaneously (DIN EN ISO 10218-2). Working persons and robots work in immediate proximity and perform a work task together. This change requires ethical, legal, and social questions to be considered.

To approach these questions in a best-practice approach, (1) basic factors of technology ethics are mentioned, (2) the need to involve all stakeholders is highlighted, (3) methodological approaches to detect ethical aspects are discussed, (4) the model for ethical evaluation of socio-technical arrangements (MEESTAR) for gathering different planes of observation is explained, and (5) within the framework of the AMICAI the MEESTAR and the failure mode and effects analysis (FMEA), a qualitative as well as quantitative analysis, are combined.

As part of this investigation potential ELSI problems and their possible causes and effects are identified and quantitatively analyzed by the Aachen Model of Identification, Classification and Analysis of ethical, legal, and social Implications. Furthermore, the technological impact is identified and demonstrated alongside potential risks, opportunities and potentials of human-robot collaboration. This contribution describes the results of applying AMICAI based research to expert workshops using the application example of a human-robot collaborative workplace (Wille et al. 2016).

2 Background

The increasing use of (collaborative) robots in manufacturing companies involves advantages as well as disadvantages. On the one hand working persons can be supported in physically strenuous or monotone tasks. On the other hand, the growth of robotic systems can cause job loss and a decline of human skills and knowledge. This dualism of technology leads to the necessity of considering an ethical point of view in the development of human-robot collaboration systems. Such questions belong to the field of technology ethics, an applied and problem-centered field which concentrates on normative uncertainties when dealing with technology. It includes moral questions of equipment and tool production and the use of technology (Bendel 2015). Technology ethics reflect on design and impact of technology. Therefore it is not concerned with technology itself, but with technology in the context of application. This reflection includes three criteria: aims and purposes of technology implementation (e.g. the support of humans at work by robotics), instruments and means which are necessary for the application of technology (e.g. materials for building a robot, location of production), and consequences that arise by using the technology (e.g. risks of production for society and environment). Examining these criteria, technology ethics specifically focuses on the moral aspects involved. Besides, they also relate to scientific and technical progress. Additionally, they consider and integrate alternative options (Grunwald 2013). An important aspect concerning technology ethics is the concept of safety. The absence of unacceptable risks and dangers for humans should be guaranteed with the operation of the system (Kagermann et al. 2013) and the so called "safety" (Liggesmeyer and Trapp 2014) must be created. Safety can be subdivided into two aspects: (1) the systems must not cause any danger for human beings and (2) the systems themselves and the data they contain must be protected against misuse (Kagermann et al. 2013). Moreover, ethical questions arise with ensuing implications for substitutability of humans by machines. Thus, it depends on the question of how far human working processes will change by increasing automation. Concerning automation, two effects appear: (1) the so called down-skill effect: in this case the demand for complex skills declines while the demand for more simple skills increases; (2) the so called up-skill effect: the number of technical monitoring tasks on the activities of the robots rises to the extend that higher skills are required. Consequently, questions about the distributive justice of tasks between humans and robots arise. As a result, on one hand a high degree of automation implies a loss of workplaces, while on the other hand the manufacturing costs for the company will decrease. Additionally, risk of an employee's instrumentalization in the work place emerges (Grunwald 2013; Dworschak 2015). Further, technology ethics deal with the usage and promotion of new opportunities that are enabled by technology—for instance when a service robot reports back errors to a factory and thereby helps the maintenance team fixing them (Bendel 2015).

2.1 Ethical Constructive Technology Assessment

When developing new technologies, various aspects need to be considered. Social, legal and ethical implications must be integrated into the process of development and design. Especially ethical aspects of new technologies should gain more attention to guarantee fair, safe and usable technologies. To make it easier for developers and designers to assess all relevant ethical problems, Palm and Hansson (2006) developed a checklist considering nine ethical aspects which need to be integrated into the process of development and design of technologies. These aspects are (1) dissemination and use of information, (2) control, influence and power, (3) impact on social contact patterns, (4) privacy, (5) sustainability, (6) human reproduction, (7) gender, minorities and justice, (8) international relations, and (9) impact on human values. Palm and Hansson describe their checklist as a tool which shall identify adverse effects of new technologies at an early stage of development. To make this possible ethical implications of technology under development should be investigated continuously. This, of course, requires a close interaction with technology developers (Palm and Hansson

2006). The checklist approach is part of a project they introduce as the so called ethical technology assessment, which is based on earlier forms of technology assessment. The main aim of the TA is to gain political control over the potentially negative effects of technological development by means of early warnings. Another form is the participatory technology assessment, which demands the participation of stakeholders like politicians, scientists, journalists etc. in the developing process. The ethical technology assessment is an extension of these forms which demands detection of potential ethical problems by means of a continuous interaction. By involving relevant stakeholders all different perspectives, interests and solutions shall be considered (Palm and Hansson 2006).

A checklist approach is one way to assess ethical problems. It certainly offers an organized way to work through aspects which need to be considered. Nevertheless it does not genuinely reveal the complexity and relations between the different aspects. This is also criticized by Kiran et al. (2015), who speak of the process of technology development as co-evolution of technology and morals. Hence, both the developed technology as well as the morals and ethics are related to each other in a complex way, by which they influence each other so that they both change over time. This is why a firm checklist is not sufficient to analyze the issue. The authors therefore suggest an ethical constructive technology assessment which analyzes ethical implications in a dynamic way. Another aspect which is criticized by Kiran et al. (2015) is that it does not take into account different cultural settings and the diversity with which users appropriate new technologies. The critique of checklist approach leads the authors to four principles the constructive technology assessment should consider. First of all there is the “subject constitution”: the developed technologies do not only influence moral frameworks and social processes at the macro-level, but also the everyday lives of their users. Then, the “accompaniment”: the ethical Constructive Technology assessment should be framed in terms of technology accompaniment rather than assessment. Third, the “technological mediation” needs to be considered: the ethical constructive technology assessment should focus on an accompaniment that is done in such a way that design practices incorporate openness to situatedness, alternative lifeworlds and changing moral routines. And at last “non-use”: the approach should take into account how technology influences users, as well as selective users and even non-users. After discussing the basic factors of technology ethics, the need to involve all stakeholders and fundamental methodological approaches to detect ethical aspects, the model for ethical evaluation of socio-technical arrangements for gathering different planes of observation is clarified.

2.2 Model for the Ethical Evaluation of Socio-technical Systems

The MEESTAR (in German: “Modell zur ethischen Evaluation sozio-technischer Arrangements”) is an ethical evaluation instrument, which was constructed for investigation and assessment of ethical questions within the scope of the study “Ethische Fragen im Bereich altersgerechter Assistenzsysteme”. With the help of this model, ethical problems and potential fields of conflict, as well as questions, potential opportunities and future fields of action can be identified for the use of socio-technical systems. Like this, ethical questions can be systemized and analyzed so that an overview of possible solutions for the use of socio-technical systems is gained. MEESTAR does not deliver prefabricated solution. It rather represents a heuristic instrument to ethically locate socio-technical systems in a structural dialogue (e.g. workshop) so that ethical reservations and concerns can be identified by employing the systems (Manzeschke et al. 2013).

The MEESTAR model contains three axes: on the x-axis there are seven ethical evaluation dimensions—care, self-determination, safety, equality, privacy, participation and self-conception—which were identified by a study as the core dimensions. On the y-axis there are four stages of the ethical sensibility—the range is from harmless implementation to rejecting implementation. On the z-axis there are three perspectives of observation—individual, organizational and social. In the following, the x- and z-axis shall be described more precisely.

With the help of these seven evaluation dimensions on the x-axis, evaluating people can lead to ethical questions in a concrete scenario and assign them to the respective dimension. Care in this context means that care, decisions and responsibility are assumed for needy persons if they are not be able to do this for themselves. This care thereby shall work towards the autonomy of the individual. Self-determination describes the autonomy of an individual, which, from a modern perspective is comparable to a maximum freedom of decision and action of the single person. Furthermore, safety either means—from an objective perspective—the protection against harm or—from a subjective perspective—the increase of a feeling of safety. Privacy shall shape an inviolable area around the individuals (Volkman 2003). Thereby privacy belongs to the sphere of the negative freedoms and security rights (Berlin 2002). With such rights and freedoms it shall be guaranteed that individuals can act freely inasmuch as they do not influence the rights and freedoms of other persons negatively. Privacy therefore is a condition for individual freedom and autonomy (Cooke 1999). Social equality (e.g. the access to age-appropriate assistance systems) is especially important. Here, both questions of intragenerational and intergenerational equality are relevant. Furthermore, participation means offering people accesses, rights and goods that enable them to live as an individual in a community together with other people. Eventually, self-conception describes the evaluation and perception of a subject towards itself which can be influenced through the evaluation of other persons. Self-conception of individual factors like age, illness and infirmity does also play an important role.

The three levels on the z-axis cover the respective perspectives of the responsibility of action. Individuals as well as corporate actors have to take responsibility for their actions (individually and organizationally). The responsibility on the social level can be summarized by the question how one would like to live in society and which rights and duties will be bestowed in this society (Heidbrink and Hirsch 2006). With these levels it can be ensured that possible fields of action will be considered from different perspectives.

An advantage of the model is that it provides a platform to discuss ethical questions in practice from the perspective of different stakeholders. However, when applying the model a disadvantage can be that the different evaluation dimensions on the x-axis might come into conflict. For instance, a strong focus on care might influence the autonomy and privacy of an individual negatively.

3 Consideration of ELSI with the AMICAI in the Context of Human-Robot Collaboration

In this contribution, existing models and methods were presented to assess ethical aspects of new technologies. All approaches offer advantages apart from aspects which need further improvement. The ethical technology assessment concept provides a method for assessment of all relevant aspects which need to be considered when developing new technologies via a checklist. This has the advantage of gaining a good overview on all the important factors. On the other hand it neglects the interactions and relation between these different factors. This aspect can be solved by using a model which illustrates these interactions. In the MEESTAR one can either see all important single factors playing a role in technology development and furthermore the way they are related to each other and to external factors. Besides, there is one important aspect that is still not considered in the model, namely the quantitative aspects of technology assessment.

On the basis of the failure mode and effects analysis (FMEA) according to DIN EN 60812 the quantitative aspects can be included. The FMEA is a method frequently used in constructive development processes for systematic analysis determining possible types of error conditions, their causes and effects on the behavior of the system. Using the Aachen model of identification, classification and analysis of ethical, legal, and social implications the MEESTAR and the FMEA, a qualitative as well as quantitative analysis are combined (Wille et al. 2016).

Within this best-practice approach, ethical, legal, and social issues of human-robot collaboration are considered. Here the context of observation is the implementation of human-robot collaboration workplaces. Subsequently for the systematic classification of ethical, legal, and social issues the MEESTAR was selected. The stakeholders include individual (e.g. user or working person), organizational, and societal aspects. As explained by the participatory technology assessment, possible problems caused by new technical developments need to be discussed by experts considering the ethical, legal, and social context. The inclusion of relevant stakeholders (e.g. designers, engineers, manufacturers, supplier, and customer) is recommended to involve all different perspectives, interests and solutions.

At the beginning, possible problems caused by the development of human-robot collaboration and the implementation of human-robot collaboration workplaces are identified. Furthermore the most likely causes of the problems and the problem effects for the stakeholders were discussed. Finally the methods used to detect the problems were examined. Additionally the severity S of the problem's effect is evaluated. Next is the quantification of the probability of occurrence *O*. In AMICAI the whole causal chain of cause, problem and problem effect is considered. The probability of detection *D* is to be quantified for the problem in combination with the method of detection. The risk priority number *RPN* is calculated as the product of *S*, *O* and *D*. In this manner, all problems are completed by row and respectively given their cause, effect, method of detection, severity *S*, probability of occurrence *O*, and probability of detection *D*. In conclusion, the problems can be ranked according to their risk priority number, meaning a higher *RPN* should be considered first. Finally, the solutions are supposed to be developed for the relevant problems that were identified. The earlier analysis helps, for example, by providing information about the problem causes (Wille et al. 2016).

As part of this work, ethical, legal, and social issues which might result from the implementation of human-robot collaboration workplaces and the accompanying change of work were addressed in several expert workshops. The expert committee consists of automation, robot gripper and robot manufacturers, system integrators, universities, end users of manufacturing systems and cooperative robot workplaces as well as of representatives of employers, social partners, and people with disabilities. In a kick off workshop general ethical, legal, and social questions were discussed in terms of the technical consequences of human-robot collaboration. Here, open questions and potential barriers as well as previous practical experiences were debated. In following workshops ELSI questions in the context of human-robot cooperation were identified, summarized and discussed in more depth. In addition, the collection of ethical, legal, and social problems was classified by means of the MEESTAR. Subsequently the various items have been discussed in a further workshop and analyzed with the help of the AMICAI. The aim is to identify potential ELSI problems in the implementation of human-robot cooperation workplaces early in the process.

4 Results

In the kick off workshop numerous ethical, legal, and social issues—first without differentiation between concrete problem causes, problems, and problem effects—were discussed. In the following workshops, after a consolidation, 25 ELSI aspects were identified. Finally, in a further workshop 15 ethical, legal, and social issues—differentiated between problem causes, problems, and problem effects—were analyzed. A summary of the results of the expert workshop is shown below (Table 1).

According to the evaluation of expert workshops the AMICAI (Table 1) for the observation context implementation of human-robot collaboration workplaces follows a number of potential ELSI problems and corresponding causes and effects. It is notable that about three fifth of ELSI problems concern individual aspects. In particular, a little less than half of the problem effects relate aspects regarding acceptance (sabotage, demotivation, lack of acceptance). The solution-oriented approach provides the possibility to focus on the problem causes and to create

Table 1 Documentation of the application of the AMICAI for the quantitative analysis of ELSI applied to a collaborative human-robot workplace

Observation context: Implementation of human-robot collaboration workplaces									
Classification		Problem-criticality					Problem prevention		
Plane of observation	Stakeholder	Problem cause (t/o/p)	Problem	Problem effect	*S*	*O*	Detection method (p/r)	*D*	*RPN*
Care	Organisation	Implementation of human-robot-collaboration workplaces (o)	Danger of breach of the employer's duty of care	Legal/financial consequences	9	5	Risk assessment/ analysis (p)	3	135
Equality	Society	The human being is substituted by robots (o)	Deficits in social fund	Widening gap between rich and poor	9	4	State budget (r)	4	144
Equality	Individual	Robot works with higher productivity/higher quality (t)	Fear of job loss	Sabotage	8	4	Robot downtime/ repair time (r)	4	128
Equality	Individual	Robot works with higher productivity/higher quality (t)	Fear of job loss	Demotivation	6	7	Days with inability to work (r)	4	168
Participation	Individual	Shortcomings in the input or output technique (t)	Communication gap between working person and robot	Serious injury	10	2	Days with inability to work (r)	4	80
Participation	Individual	Shortcomings in the input or output technique (t)	Communication gap between working person and robot	Demotivation	6	7	Survey after initial operation/ employee interview (p)	5	210
Participation	Organisation	Shortcomings in the input or output technique (t)	Communication gap between working person and robot	Production errors	7	5	Quality control (r)	4	140

Participation	Organisation	Shortcomings in the input or output technique (t)	Communication gap between working person and robot	Low productivity	6	7	Production figures (r)	4	168
Privacy	Individual	Sensors of the robot or workplace (t)	Working person feels monitored by sensors of the robot or workplace	Lack of acceptance	6	6	Survey after initial operation/ employee interview (p)	5	180
Safety	Individual	Technical defect (t)	Robot violates the working person	Serious injury	10	2	Days with inability to work (r)	4	80
Safety	Organisation	Technical defect (t)	Robot violates the working person	Legal/financial consequences	9	2	Legal department (r)	4	72
Safety	Individual	Robot falls below the comfort distance (p)	Working person feels harassed by the robot and is afraid	Physicall illness	9	3	Survey after initial operation/ employee interview (p)	5	135
Self-concept	Individual	Implementation of human-robot-collaboration workplaces (t)	(Social) forced to work on a human-robot collaboration workplace	Demotivation	6	7	Survey after initial operation/ employee interview (p)	5	210
Self-concept	Society	Implementation of human-robot-collaboration workplaces (t)	Gap between technologically aware generation and people who are not so technophilic	Social unrest	9	1	Public opinion poll (p)	7	63
Self-concept	Individual	Lack of acceptance (p)	Human-robot collaboration is rejected	Sabotage	8	4	Robot downtime/ repair time (r)	4	128
Self-concept	Organisation	Lack of acceptance (p)	Improper use of the robot	Low productivity	6	7	Production figures (r)	4	168

(continued)

Table 1 (continued)

Observation context: Implementation of human-robot collaboration workplaces									
Classification		Problem-criticality					Problem prevention		
Plane of observation	Stakeholder	Problem cause (t/o/p)	Problem	Problem effect	*S*	*O*	Detection method (p/r)	*D*	*RPN*
Self-determination	Individual	Robot determines work content and cycle time (o)	Demotivation, lack of tolerance	Sabotage	8	4	Survey after initial operation/ employee interview (p)	5	160
Self-determination	Organisation	Robot determines work content and cycle time (o)	Demotivation, lack of tolerance	Low productivity	6	7	Production figures (r)	4	168
Self-determination	Individual	Self-learning robot takes successively the work already done by the working person (o)	Feeling of no longer being needed	Demotivation	5	7	Survey after initial operation/ employee interview (p)	5	175
Self-determination	Individual	Self-learning robot takes successively the work already done by the working person (o)	Human-robot collaboration is rejected	Sabotage	8	4	Robot downtime/ repair time (r)	4	128
Self-determination	Individual	Robot determines work content and cycle time (o)	Overburdened	Inability to work	9	3	Empirical study (p)	2	54

Self-determination	Individual	Robot determines work content and cycle time (o)	Overburdened	Inability to work	9	3	Days with inability to work (r)	4	108
Self-determination	Individual	Robot determines work content and cycle time (o)	Overburdened	Inability to work	9	3	Survey after initial operation/ employee interview (p)	5	135
Self-determination	Organisation	Robot determines work content and cycle time (o)	Overburdened	Production errors	7	7	Quality control (r)	4	196

Problem cause t: technical, o: organizational, p: personal-related
S =1 Severity of the problem’s cause from (1) insignificant to (10) catastrophic
O = Probability of occurrence of the causal chain from (1) improbable to (10) very probable
D = Probability of detection before effects of the problem occur from (1) almost certain to (10) completely uncertain
RPN = Risk Priority Number as the product of S, O and D from (1) very low to (1000) very high
Detection method r: reactive, p: preventive

reasonable measures consequently. On the basis of the requirements of an ergonomic human-robot collaboration and the TOP-model technical, organizational and personal-related/behavioral-based measures should be taken into account (Schlick et al. 2010). For example, Brandl et al. (2016) describes technical factors influencing distances that humans will accept between themselves and an approaching service robot. In the area of personal-related measures Broehl et al. (2016) derives factors for increasing acceptance of robots in production through the technology acceptance model for human-robot cooperation in production systems.

5 Discussion and Conclusion

This best practice approach shows that the solution-oriented application of the Aachen Model of Identification, Classification and Analysis of ethical, legal, and social Implications is an essential tool to detect potential ELSI issues in applied research projects at an early stage. In this contribution AMICAI is appliedon the basis of workshops in the context of the implementation of human-robot cooperation workplaces. During planning, execution, and evaluation of the expert workshops, the methods shown in the fundamentals were useful to understand to background of ELSI.

The approach of participatory technology assessment (Palm and Hansson 2006) was helpful to involve the relevant stakeholders in the development process of human-robot collaboration workplaces early in the process. The ethical technology assessment (Palm and Hansson 2006) and the ethical constructive technology assessment (Kiran et al. 2015) showed which aspects should be taken into account in establishing ethical, legal, and social implications.

The Aachen model of identification, classification and analysis of ethical, legal, and social Implications (Wille et al. 2016) used in this contribution based on the model for the ethical evaluation of socio-technical arrangements (Manzeschke et al. 2013) and the FMEA (DIN EN 60812)—leads to a systematic overview of the ethical, legal, and social implications that may arise in the implementation of human-robot collaboration workplaces. The previously described AMICAI approach allows the identification of ethical, legal, and social implications early on in an applied research project, quantify their criticality, and prioritize them based on their relevance.

In principle, the application of AMICAI in expert workshops is adopted to raise ethical, legal, and social issues in the implementation of human-robot collaboration workplaces. In a first step the needs and expectations of stakeholders are interrogated and considered during the course of the workshops. Moreover, it should be taken care of that in heterogeneous groups particularly the participants are sufficiently familiar with both the wording and the method to be used. Furthermore it should be ensured that the causal chains of cause, problem and effect are prepared consistently. During implementation it is to be remembered that the classical restrictions of the FMEA are obviously the limitations for AMICAI as well. Thus, the multiplication of the criteria S, O and D is not defined in a strict mathematical sense due to the ordinal scale. Also, on the one hand it is not guaranteed that similar risks are assigned the same *RPN*, and on the other hand it is possible that there are risks with the same *RPN* that are not equally acceptable. This stresses the fact that the *RPN* are only supposed to be an orientation and not deemed to be interval-scaled “hard facts”. However, they are suitable for arranging and prioritizing ethical, legal, and social implications.

Depending on the requirements future workshops can go into more detail and focus on individual ethical, legal and, social issues. Further considerations will be needed in order to develop solutions and design recommendations based on the causal chains of problem cause, problem and problem effect and on the detection method.

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Human-Oriented Productivity Management as a Key Criterion for Success in the Digitalised Working World

Patricia Stock and Sascha Stowasser

Abstract

The world of work and business is constantly changing. At the moment, the digitalisation megatrend is significantly changing framework conditions for companies with a range of new requirements. Within this context, a growing desire for more flexibility, which can be achieved thanks to new developments in information and communication technology, can be seen both at companies and among employees. To ensure the long-term success of digitalisation at companies, work must be organised with a human-oriented focus in all operating areas. Human orientation has both a direct as well as an indirect impact on productivity. For efficient human-oriented productivity management, new methods and tools in industrial engineering are required, which would allow the digitalised working world to be analysed and shaped.

Keywords

Digitalisation • Industrial engineering • Productivity managament • REFA

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1 Digitalisation as a Driver of Change in the World of Work and Business

1.1 Transformation of the World of Work and Business

The world of work and business is currently undergoing a fundamental change initiated by various megatrends. Changing information and communication technology and the resulting digitalisation of the world of work and business is one of these megatrends [for more detailed information, see e.g. BDI (2011), Rump and Walter (2013), Spath et al. (2013), REFA-Institut (2016)]. Digitalisation unlocks new forms of flexibilisation potential for companies to create work and value-adding processes by primarily providing access to intelligent tools, instruments and automation, production and networking technologies as well as access to globally distributed information, knowledge, skills, resources, work partners and markets (Picot and Neuburger 2013). For employees, this results in new qualification requirements and changes the strain that is placed on them. In particular, the rising acceleration of processes, the increasing speed of change and the consolidation of work have resulted in new employee requirements (Rump et al. 2011).

Furthermore, not only technology is changing–employees are changing, too. Younger generations (known as "digital natives") grew up with these new technologies, which is why they are less afraid of using them and have an intuitive and rather playful approach to these technologies. On the other hand, older generations (known as "digital immigrants") first need to learn how these technologies are used [for more detailed information, see Prensky (2001a, b), Palfrey and Gasser (2008)]. This requires various strategies for using new technologies and the qualifications that are needed in order to use them.

As a result of the value shift, our perception of work has also tremendously changed. Employees also want the time they spend at work to be meaningful, fulfilling and stimulating. A person's job should not compete with his or her private life but, where possible, harmonise with it (Zukunftsinstitut 2011). As a result, employees are ever less willing to adapt to external conditions imposed by companies that do not meet their expectations, wishes and needs (e.g. Zukunftsinstitut 2011; XING 2014).

Due to the demographic change, there is growing evidence of a skills shortage that is forcing companies to actively seek out new employees and retain them through attractive working conditions, while also giving employees a new sense of confidence. In light of this, companies must always consider their employees' wishes and needs because of their growing significance for companies. Companies that pursue corporate goals exclusively and lose track of their employees in the process will face significant problems in the medium term.

1.2 The Flexibilisation of Work

Overall, a growing desire to make work more flexible can be seen both at companies and among employees, although both sides want to be able to control this flexibility. New information and communication technologies offer flexibilisation opportunities. This means that it is the company's duty to identify business potential that could be exploited in a useful and cost-effective way using digitalisation. Special attention should be paid to the requirements and needs of employees. This includes the creation of framework for human-oriented personnel deployment. The qualifications and inclusion of existing staff and the acquisition of additional, suitable skilled workers provide a basis for this. In the context of demographic change, the professional experience of older employees in particular is becoming increasingly significant as well. However, since these employees are usually unable to intuitively master the new technologies of digitalisation as "digital immigrants", they need to be given access to these technologies by means of suitable qualification measures to allow them to further contribute their knowledge and experience to the company as well.

In addition, flexible work opportunities created on the basis of digitalisation need to be implemented on a company-specific basis to allow the company, customers and employees to make use of this flexibility in the best possible way. There are various schemes for flexible work: In the case of trust-based working hours, an employee's performance is measured exclusively on the basis of the results of their work. In addition, time tracking and attendance checks do not apply. In the case of mobile work or telework, employees carry out at least part of their work outside the employer's premises–for example, in cafés, during train journeys or in co-working spaces. In the case of home-based work, employees work at home. Offices that are organised based on the open-plan principle do not provide employees with a fixed workstation. In most cases, there are various workstation types that are explicitly designed for different employee activities (e.g. rooms allowing people to concentrate on their work, creative rooms or conference rooms). This allows each employee to book a workstation for the task at hand, where they can complete this task in the most efficient way.

The relevant legal requirements must be observed for the design of flexible work. In Germany, the Works Constitution Act, the Occupational Safety and Health Act, the Federal Data Protection Act and the associated regulations are particularly relevant here as they set the framework for flexible work.

For the purpose of human orientation, both the works council and employees need to be included in the organisational process. However, new work flexibilisation schemes all require an adequate corporate culture, which is often only created by means of suitable awareness and qualification measures. Both managers and employees are called upon here to create a win-win situation as partners.

The systematic and methodical exploitation of digitalisation and flexibilisation potential can be supported using human-oriented productivity management. Human-oriented productivity management thus forms the basis for the implementation of digitalisation within the company by combining profitability and human orientation. Human-oriented productivity management therefore interprets the consideration of employee interests as a key criterion for success, which can also have a positive effect on productivity.

2 Human-Oriented Productivity Management as the Basis for the Sustainable Implementation of Digitalisation

2.1 Tasks of Productivity Management

The aim of productivity management is to increase a company's productivity. Productivity is generally defined as the ratio of output to input (Gabler Wirtschaftslexikon 2015). For instance, this can be the amount, volume or weight of the products manufactured or special performance parameters, such as gross register tonnage in the case of a shipyard. The denominators are measurable values for the input factors "workforce" (number of employees, working hours, remuneration), "operating means" (number, value) or "material" (quantities, value). The output and factors used (input) can also be valued in money at all times and used in the productivity ratio.

To determine the aggregate productivity of a company, the company's overall performance needs to be used accordingly as an output value (also known as the gross production value). Various parts of the overall performance (e.g. net value added) can also be used for the analysis of partial productivity (e.g. labour productivity). Ideally, the objective should be to consider the partial performances that are relevant to the partial productivity in question on a nuanced basis (Dikow 2006). Companies operating in differing industries or with different production structures can be compared on this "standardised" basis.

Various influential factors that have an impact on the output (revenue or added value), input (workforce, work equipment, materials) and throughput (optional factors; e.g. process organisation, quality capability) can be identified (Nebl and Dikow 2004; REFA-Institut 2016; see also Fig. 3). These influential factors can be used as a lever to increase productivity. In doing so, there are always interactions between the various influential factors. This is why it is impossible to improve all productivity factors at the same time. Productivity management generally focuses on the influential factors that can provide the best support in the pursuit of corporate goals.

A methodical and systematic approach that includes planning, controlling, implementation and monitoring measures is recommended (Dorner and Stowasser 2012; Dorner 2014; DIN EN ISO 9241–2 1992). With REFA methods, the following input factors in particular can be influenced: "workforce" (the ability to perform and its maintenance, the use of available capacity and work organisation), "operating means" (available capacity and its use) and "materials" (material flow and lead time) [for more detailed information, see REFA-Institut (2016)].

Work productivity is considered as one of the key indicators to determine a company's efficiency. In addition to internal and cross-business comparisons, time flow is also particularly significant in this context (Dorner 2014; DIN EN ISO 9241–2 1992). For example, work productivity can be specified as the number of employees involved, working hours spent or staff expenses in euros.

2.2 Human Orientation as an Operating Criterion for Success

In addition to profitability (i.e. the ratio of income to expenses), human orientation also plays a key role in the organisation of work. People are shaped by the work that they do. Well-being, health and personal development are influenced by work and can either be negatively or positively impacted. Therefore, work needs to be organised in an acceptable way on the economic, human and social levels. Both objectives–economic efficiency and a humane organisation–can be complementary, but also incompatible (Nullmeier 2011).

The necessity of human orientation is nothing new. In the 1970s, working conditions in Germany improved as part of a government-funded research programme to humanise working life (In German: "Humanisierung der Arbeit") in order to reduce the number of accidents and occupational illnesses. The amendment to the Works Constitution Act strengthened the rights of co-determination of employees and the works council [for more detailed information, see Nullmeier (2011)]. Here, the focus was on "humane work", i.e. the extent to which a job fulfils the physical, mental and social requirements and needs of an individual (Schlick et al. 2010). However, the discussion on digitalisation and Industry 4.0 usually focuses on technological aspects at present (cf. Jeske 2015) while the changes that need to be made to the structure and organisation of work are usually neglected. As a result, human orientation is not the focus of many companies at the moment.

In the area of human orientation, work is organised in line with the physical, mental and social requirements of the individual. According to Hacker (1986), there are four assessment levels in the organisation of work, which are structured hierarchically. As a result, the criteria of the lower levels need to be met before other levels can be considered. The assessment levels of humane work are (Hacker 1986):

– **Practicability:** Physical and mental requirements, such as body mass, physical strength or cognitive ability, need to correspond to the requirements of the task.
– **Safety:** Carrying out work–even over a lengthy period of time while taking breaks and holiday into account–should not result in any damage. For example, adverse health effects as a result of work-related accidents, occupational illnesses or contaminants need to be prevented.
– **Freedom from impairment:** Work-related harm is the result of strain or stress due to performance requirements–for example, after being qualitatively or quantitatively over- or underchallenged. Work-related harm can be prevented if the damage caused by high levels of stress or strain can be reversed in the short term by recovering during breaks and free time, for example.

– **Personality-building:** Work should offer opportunities to develop one's personality during work activities.

For every assessment level, there are specific operational areas and organisational fields where the criterion in question can be implemented. These are the workstation, work task, technical and social work environment and the individual. The organisation of the workstation, work task and the qualifications and development of employees have been REFA's core competences for decades. Approved REFA methods and tools are thus also suitable for supporting companies when fulfilling human-oriented requirements.

2.3 Impact of Human Orientation on Productivity

Human orientation can initially be described using the criteria provided in Sect. 2.2: practicability, safety, freedom from impairment and personality-building. The lower levels "practicability" and "safety" of this schema primarily affect the sub-factor "the ability to perform and its maintenance" of the "workforce" input factor of productivity (Fig. 1). An employee's ability to perform is primarily determined by their qualifications in addition to their physical and mental abilities and skills. This can also be ensured and promoted by means of qualification measures, training and further training in addition to occupational health and safety, the organisation of the workplace and measures to promote health.

By contrast, the levels "freedom from impairment" and especially "personality-building" have an indirect and significantly more complex and multi-faceted impact on productivity, and thus affect other input factors as well.

For example, "maintaining the efficiency" of operating means can be facilitated significantly by a well-trained employee who is willing to perform, makes use of the optimal condition of work equipment, reports potential issues to maintenance at an early stage or even rectifies them.

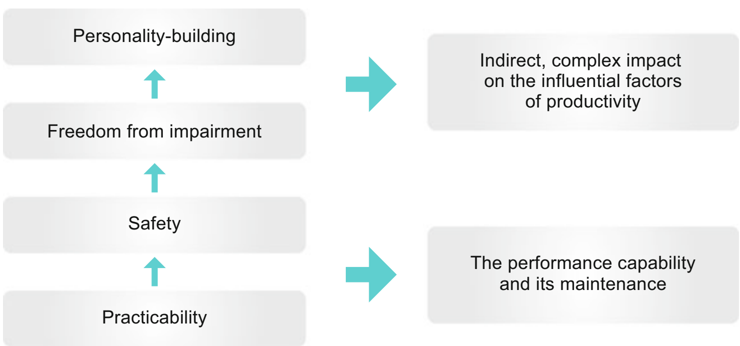

Fig. 1 Impact of human orientation on productivity (source: REFA-Institut 2016)

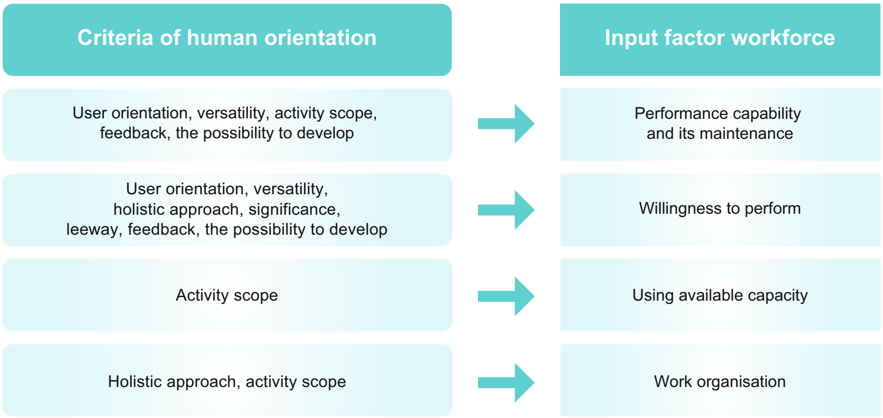

Fig. 2 Impact of human-oriented criteria on sub-factors of the "workforce" input factor (source: REFA-Institut 2016)

The assessment criteria of human orientation can be divided into other sub-criteria–for example, in accordance with DIN EN ISO 9241–2 (1992) (see Fig. 2, left). Figure 2 illustrates the direct effects of human-oriented criteria on the "workforce" input factor. For example, selected effects are [for more detailed information, see REFA-Institut (2016)]:

– **User orientation**, which considers the comparison between the employee's abilities and the requirements of the task.
– **Versatility**, which allows for the development of various skills and abilities and prevents one-sided strain.
– **The possibility to develop**, which promotes the development of existing skills and the acquisition of new ones.
– **Activity of scope**, which supports the autonomous situational use of available capacity in line with capacity requirements.
– The characteristics of a **holistic approach** and **activity of scope** can support a work organisational structure that promotes productivity.

Human-oriented work organisation has both direct and indirect effects on the individual's performance and thus on labour productivity as well. However, human orientation also has a significant impact on other influential factors in productivity. This is because these factors are directly or indirectly influenced by the performance offer and thus the employee's responsible actions which are closely associated with this (REFA-Institut 2016; cf. Fig. 3; fields marked in dark blue: performance offer; fields marked in light blue: sub-factors of productivity influenced by the performance offer). This does not include: