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SOCIAL SUSTAINABILITY IN THE DEVELOPMENT OF SERVICE ROBOTS

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Abstract
We introduce the concept of social sustainability, intertwined with ecological and economic aspects, to the field of service robots and comparable automation technology. It takes a first step towards a comprehensive guideline that operationalizes and applies social sustainability. By applying this guideline to the project MURMEL we offer a concept that collects and rates social key issues to visualize their individual importance. Social sustainability is an important and often overlooked aspect of sustainable technology development which should be considered in the early development phase.

Keywords: sustainability, case study, design guidelines, automation, service robots

1. Introduction

Progress in automation technology offers new opportunities to advance the service sector. However, new technologies in robotics may change established social settings like workplaces, public spaces and institutions. To tackle the challenges and risks arising from this new trend, we consider the approach of integrating sustainability aspects into product design and development. While different Ecodesign tools and methods have been developed in the last years (Kattwinkel et al., 2018), they by definition only consider ecological aspects in product development (DIN EN ISO 14006, 2011).
In line with the more holistic view of Sustainable Product Design (SPD), Buchert and Stark emphasize the notion of including all three dimensions (social, ecological, economic) into conceptual design. However, the social sustainability goals described in this publication are rather vague. The tool is based on quantitative indicators only, so the authors give a limited description of social sustainability (Buchert and Stark, 2018). We argue that the emerging field of service robots calls for a far more detailed analysis, including qualitative approaches to this aspect.
Other publications have focused more on the implementation of sustainability than on its specific factors, because determining goals and scope is still a challenging task for many companies (Schulte and Hallstedt, 2018b). As Kattwinkel et al. also stated, this approach neglects the use phase of the product, wasting a huge potential for sustainability considerations and according improvements (Kattwinkel et al., 2018).
Consequently, we analyse the use phase and determine the overall impact of service robots on social sustainability. We argue that the manner and the extent of such an impact can be influenced during the product development and design phase. We analyse social sustainability of our product using social life cycle assessment (S-LCA). This method is comparable to an environmental life cycle assessment

(E-LCA), following the same framework (DIN EN ISO 14040, 2006). Since we apply S-LCA in early concept phase of robot development, we face the challenge of lacking detailed product data. Nevertheless, we identify the elements of an S-LCA which can be applied in concept design using categories defined in (Benoît-Norris et al., 2011). As Schulte and Hallstedt et al. express the idea to address social aspects in the form of risk management (Schulte and Hallstedt, 2018a), we, in a similar way, make use of a visual tool acting as an early warning system, detecting risks and locating the most relevant aspects of social sustainability during the concept phase. Eventually we propose a guideline, which accompanies conception and design of automated service robots.

2. Trends and future perspectives on autonomous service robots

Robots have long been established in the industrial environment with their numbers still rapidly growing according to global market revenue forecasts (IFR Statistical Department, 2019; Tractica, 2018b). While industrial production traditionally represented the majority of the global market for robots, this is recently being complemented by the branch of service robots having a noteworthy impact (Tractica, 2018a). Following this prediction, we can see a shift in the scope of application for robots towards the service sector, interacting closely with humans. Current projects (see Figure 1) show the feasibility of robots capable of more advanced and sophisticated tasks than the aforementioned (Bauer et al., 2009).

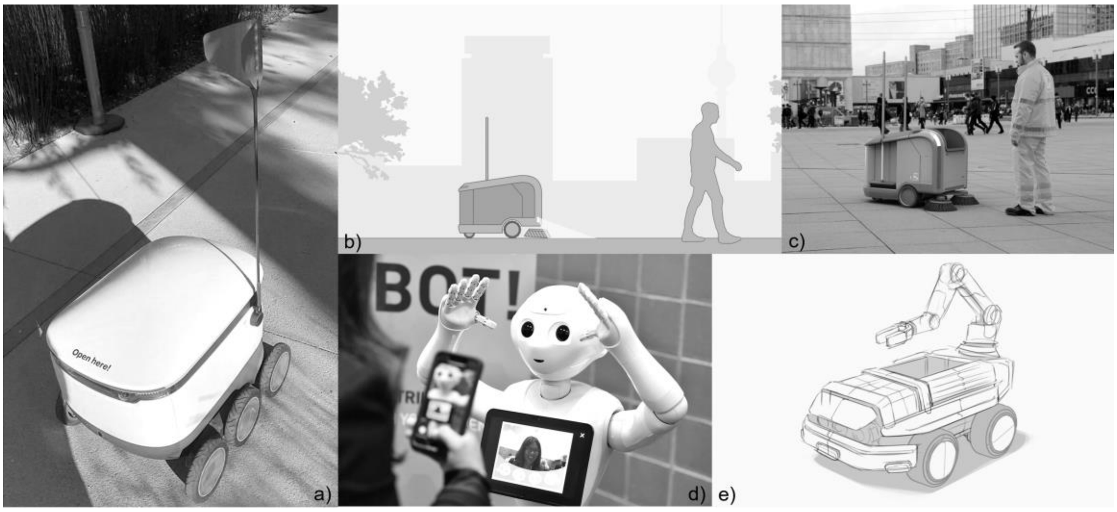

Figure 1. Projects and concepts for urban service robots; a) Starship, b) and c) Sweep, d) Pepper, e) MURMEL[1]

Recently developed service robots are able to take on dangerous tasks in unhealthy environments, as shown by the Projects SIAR and AZUKA (Alejo et al., 2016; Kapusi and Franke, 2019). Another relevant area is the logistics sector, which poses the third biggest share of service robot revenues forecasted (Tractica, 2018a). Fully autonomous prototypes like Starship (Boysen et al., 2018) illustrate how service robots can operate in crowded urban environments. Other concepts suggest an approach to given tasks that relies on human-machine cooperation, as shown in the case study SWEEP (Schneider and Lindau, 2019) as well as the Project MURMEL (MPM TU Berlin, 2019), whose set goal is to support municipal services in growing cities. For the city of Berlin, Germany, Fraunhofer in cooperation with the sanitation department has launched the Project 2030+ (CeRRI Fraunhofer, 2019), embracing the idea of a close cooperation between humans and robots to achieve sustainable waste management. Even closer contact between these parties will for example be established in the field of elder care and nursing, where robots like Pepper (Pandey and Gelin, 2018) are being introduced.

[1] a) ‘Food delivery robot is bringing my coffee’ by Ted Drake, licensed under CC BY-ND 2.0 / Desaturated and cropped from Original; b) and c) ’Workflow Sweep’ and ‘Interaktion Sweep’ by Jonas Schneider and Valentin Lindau; d) ‘DG1_9780’ by collision.conf, licensed under CC BY 2.0 / Desaturated from Original

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Given all these developments and forecasts, we assume a steady increase of robots entering society not only in the workplace but also in public spaces and institutions. Therefore, the question how to deal with the growing social impact of robots has to be answered in the near future.

3. The dimensions of sustainable development

The concept of sustainability was first mentioned in the 18th century. It has only become more precisely defined in the last 30 years for example by the Brundtland report (Brundtland, 1987). Recently three main dimensions of sustainability have been defined: social, ecological and economic.
All three dimensions have strong interactions and dependencies, which can be visualized in different formats, (McKenzie, 2004) as shown in Figure 2.

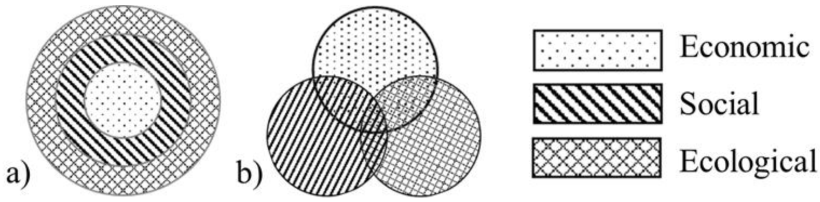

Figure 2. Two variations to visualize the interrelatedness of aspects of sustainability (adapted from McKenzie, 2004)

Sustainability may be understood as three interlaced circles (Figure 2a). The innermost circle represents economic sustainability, the circle in the middle social sustainability and the outermost circle ecological sustainability. Following this model social sustainability depends on ecological - and economic sustainability depends on social and ecological sustainability (McKenzie, 2004). Another illustration shows the three dimensions as overlapping circles (Figure 2b). It represents all dimensions as equally weighted (McKenzie, 2004). They exist individually as well as in connected systems which need to be balanced constantly to keep a society sustainable and resilient (Littig and Grießler, 2005). Researchers often refer to sustainability in general, when in fact they address only one dimension, whereas the triple bottom line (Elkington, 1998) explicitly demands equal attention to all three dimensions (Alhaddi, 2015). Economic sustainability, along with technological and operational concerns and in the recent past also ecological considerations have been frequently addressed in many research projects (Göhlich and Gräbener, 2016; Watz and Hallstedt, 2018).
Another, comprehensive approach to address all dimensions of sustainability is “Transforming our world: the 2030 Agenda for Sustainable Development”, where 17 sustainable development goals (SDGs) are defined (UN, 2015). The SDGs are more precise than the models described above and we could demonstrate which goals are related to the development of urban service robots. A comprehensive analysis of all dimensions or all SDGs is outside the scope of this paper, since we focus on social sustainability. Nonetheless, we consider their possible interdependencies in the identified key issues.

4. Social sustainability in automation initiatives

While it is already difficult to determine an ecological or economic status, measuring social sustainability is even more complex. Defining a desirable ‘socially sustainable society’ is not a matter of descriptive assessment. While Biart argues that one has to differentiate between ‘sustainability’ and ‘desirability’ when trying to specify a socially sustainable condition (Biart, 2002). Both, normative and descriptive aspects will play an important role in determining a set of goals for social sustainability (Littig and Grießler, 2005).
To adequately define and operationalize social sustainability, markers to measure quality of life and its potential longevity in a given society have to be agreed upon. Since this is an open issue, we intend to start a process of academic consideration of the overall topic by offering a first estimate of the existing issues at hand. We follow the definitions of social sustainability by Littig and Grießler (2005) and Cocklin and Alston (2002) that among other things highlight work and education, infrastructure, social cohesion and institutions as important for socially sustainable conditions. Littig and Grießler especially emphasize the importance of work in this regard (Littig and Grießler, 2005). Furthermore, we considered the SDGs “Sustainable cities and communities”; “Decent work and economic growth”;

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"Good health and well-being"; "Gender equality" and "Reduced inequalities". In the following, we approximate the most important areas of sustainability related to robotics.

4.1. Quantitative effects on work

One of the most controversial aspects of automation technology is the influence that it might have on the global labour market. As multiple studies confirm (McKinsey and Company, 2017; OECD, 2019), a substantial influence on the demand for human labour is to be expected well within the next decade. Some experts are not concerned about this development as they claim that we can extrapolate from historical data that, as some jobs will be lost to automation, others (and better ones at that) will be created in the process (Lowrey, 2018). Others however, while agreeing on the assessment of the existing data, fear a kind of singularity event in the near future of automation technology that leaves few tasks that can be performed better or cheaper by a human than a machine (Brynjolfsson and McAfee, 2016; Ford, 2016). We claim that, when it comes to policy, precaution is advisable, as the consequences of such an event could be potentially devastating for social order and cohesion. Some of these consequences might be eliminated by replacing our current work-based system with something else, e.g. a universal basic income. This addresses consequences like large sections of the population retaining their livelihood, but leaves others untouched - for example, the working population's dwindling political leverage and losses in social cohesion and structure (Littig and Grießler, 2005).

4.2. Qualitative effects on work

The way that technology affects our work has changed continuously over the years. In the wake of new developments in Artificial Intelligence and robotics, it is now possible to automate complex and dynamic tasks (Bauer et al., 2009). Therefore, the idea that machines take over monotonous labour to enable humans to do "more interesting things" continues to lose accuracy. On the contrary, some of the jobs that now exist due to the introduction of new technology are extremely monotonous or otherwise mentally straining (Newton, 2019). Although it is less common for jobs to become more physically problematic and dangerous because of partial automation, the introduction of robots into the workplace can create new possibilities for accidents. Work places may become less satisfying due to the polarization of the labour market (OECD, 2019). While some jobs, that require little to no qualifications, are currently not paid well enough to make automating them a viable option, some other well paid positions require a high level of (human) skill and therefore are not automatable (at this point in time). As a result, 'middle-class' jobs may diminish. The resulting imbalance increases social disparity in workplaces and society in general, especially in advanced economies (McKinsey and Company, 2017).

4.3. Peripheral effects

When looking beyond directly affected workers and at the general population instead, three main issues should be considered when it comes to automation technology in a social context. Firstly, enabling AI to make decisions affecting human life and wellbeing or implementing autonomous machines that might potentially be a threat to humans in specific circumstances comes with ethical questions that have not been properly discussed yet (Holder et al., 2016). Precaution is very important in this regard: formative evaluation of expectations and needs of affected people as well as establishing binding guidelines and laws that answer questions of responsibility and liability will have to precede the implementation of said technologies into the public sphere.

Secondly, services in areas like nursing, rehabilitation or elder care are somewhat automatable, yet we assume that the human contact they establish can in many cases be valuable for all parties involved and should therefore not be reduced. Automation might therefore have a detrimental effect on the quality of life of people depending on these services. However, we want to assert that this is not necessarily an exception to the rule that there is great merit in using automation technology to make all services more efficient and satisfying. It could, for instance, be used to exclusively automate the tasks that keep service workers from maintaining contact with their clients or patients.

Lastly, as robots can feel disruptive in workplaces (Smith and Carayon, 1995), we assume that urban environments can become uncanny or even hostile to their occupants if they are increasingly populated

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by robots and partially controlled by automated systems (Dempsey et al., 2011). We furthermore assume that to prevent this from happening, those who inhabit the affected spaces need to be included in a continuous evaluation process.

4.4. Accessibility and equal opportunity

Automation technology can reduce physical barriers and accessibility issues in the workplace and therefore equalize opportunities. However, with technological literacy having become an important form of educational capital (McGregor et al., 2004), new accessibility issues are created along the way. Considering how automation will continue to relocate workers into new tasks tending to require a higher level of technological literacy, a worrying possibility for a new global precariat arises. Additionally, a growing tech industry, combined with dwindling human employment in other industries, means that employment habits in the former will extend their influence. This means that current equality issues could increase, for example below-average employment of women (Morozova-Buss, 2018). On the smaller scale of specific automation initiatives, it should be considered which tasks are automated and created along the way and which specific equality and accessibility issues this might imply.

4.5. Relevance in the contemporary discourse

Although social sustainability is of particular relevance for the automation technology and robotics sector, it does not seem to be a well-established concept in the corresponding academic discourse. This may be due to the fact that the currently more commonly explored term (corporate) social responsibility covers many of the same subject areas. However, we argue that the term social sustainability offers at least two benefits compared to simply referring to responsibility when discussing short-term and long-term societal issues. Firstly, it ties all discussed subjects into the three-aspect-model of sustainable development (see Section 3) and therefore comes with a more holistic and considerate understanding of the issues at hand. Secondly, it allows for a normative understanding of social progress.

4.6. Interim conclusion

To achieve a comprehensible framework that follows a precautionary principle, we collected all issues addressed in relevant literature that were applicable to service robots (4.1 to 4.4) and condensed them into ten possible key effects to be considered in the development of service robots. They follow the same clustering as the section above which we developed to encapsulate all identified issues while tying related subjects together. Quantitative effects include loss of employment (McKinsey and Company, 2017; OECD, 2019) and reallocation of workers (Wischmann and Hartmann, 2018). To elaborate on the latter: in some instances, workers will be put into new positions that are exclusively 'operative' (Wischmann and Hartmann, 2018), do not relate to their skill sets and former work experience or will otherwise be unsatisfactory to them. We suggest that workers should optimally be included in adjacent processes and tasks, where they can utilize the skills they acquired throughout their previous employment. Moreover, the new positions created should contain 'dipositive' (Wischmann and Hartmann, 2018) tasks and elements, so that people with experience in the field are included in the decision-making process.

Qualitative effects on work comprise mentally and physically straining tasks (UN, 2015), other losses in task quality and the polarization of qualification levels (OECD, 2019; UN, 2015). Peripheral effects contain questions of ethical responsibility (Holder et al., 2016), loss of socially valuable contact in services and the creation of hostile environments (Dempsey et al., 2011). Further elaboration on applicability and urgency of these aspects and how they can be considered next to each other can be found in section 6.

5. Guideline for the implementation of social sustainability in a development process

To operationalize social sustainability in service robotics, we developed a guideline which relates the key social issues around automation projects mentioned above with different types of automation. The guideline recommends a general approach to evaluate the social effects of automation and it relates the

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interdependencies of the issues with other dimensions of sustainability. The guideline can be found online[2].

5.1. Notes on evaluating social sustainability

While aspects like gross losses in employment can be quantitatively measured, when it comes to evaluating other aspects of social sustainability a consideration of key stakeholders, related to the methodology of S-LCA, is inevitable. We recommend a series of 'social audits' (McKenzie, 2004) that collect the opinions and needs of affected groups. Effects on work should be evaluated with workers' actual concerns and problems in mind, thereby including them in the decision-making process. In other cases, a social audit focused on a broader spectrum of affected groups is also invaluable and should be held repeatedly, starting as early as possible to formatively influence the development process. The same goes for issues of accessibility and equal opportunity, which constitute the last category.

5.2. Interdependencies of the dimensions of sustainability

Following the understanding of the dimensions of sustainability as interlaced circles or the theory of the triple bottom line (see Section 2), every domain of social sustainability has at least weak interdependencies with the ecological and economic dimension. Dividing these interdependencies into weak and strong offers a way to further define areas of social sustainability (see Table 1). The interdependencies illustrate which social implications of automation can be addressed in isolation and in which areas the dimensions of sustainability have to be addressed comprehensively.

Table 1. Interdependencies - weak = light grey; strong = dark grey

Areas of Social Sustainability		Sustainability Interdependencies	
		Ecological	Economical
Quantitative effects on work	Loss of Employment		
	Repositioning		
Qualitative effects on work	Monotonous/ Mentally Straining Tasks		
	Dangerous/ Physically Straining Tasks		
	Losses in Position and Task Quality		
	Polarization of Qualification Levels		
Peripheral Effects	Ethical complications/ Responsibility Issues		
	Loss of Socially Valuable Services/ Contacts		
	Creation of Hostile Environments		
Accessibility and Equal Opportunity	Decreasing Accessibility and Equal Opportunity		

A change in the area of *Quantitative effects on work* will for example lead to *Loss of employment* and *Reduction of working hours. Loss of employment* directly influences national economics and *Reduction of working hours* directly influences business economics. Hence, strong interdependencies between the social and economic dimension of sustainability can be expected. An example of strong interdependencies between the ecological and social dimension can be found in the area of *Qualitative effects on work*. Concurrently, human toxicity is addressed in ecological life cycle assessments as an impact category (Owens, 1996) and is a concern within social sustainability as well (Walter and Spillmann, 1999). Another strong interdependency is found in the area of *Quantitative effects on work* due to the automation of tasks in which human labour is replaced by machines. If tasks are performed by machines, energy

[2] https://www.mpm.tu-berlin.de/fileadmin/fg89/PDFs/Forschung/Guideline.pdf

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needs to be provided. This can mean an increased energy consumption when specific tasks are automated which were previously performed by humans. Even in cases in which a task was previously performed with the help of a non-automated machine, changes in energy consumption are expected. One example for this is the automation of vehicles. Researchers expect energy savings, e.g. due to less acceleration and braking, but also a modal shift from public transportation to autonomous vehicles which could lead to an increased energy demand (Pakusch et al., 2018). This example underlines that automation affects ecological sustainability. However, it remains unclear whether specific implementations lead to improvements or a decline in ecological sustainability. Consequently, it is currently not possible to state whether the dimensions of sustainability cooperate or compete in specific cases.

6. Application to an urban service robot

To illustrate how to use the introduced guideline in the context of a specific project, we apply the guideline to the automation project MURMEL currently developed at Technische Universität Berlin.

In a first step we identify the factors in the four suggested areas that are relevant for the project. Therefore, the concept of the service robot has to be considered in the context of its associated process and possible environment. The project MURMEL aims to improve the process of emptying litter bins in an urban environment mainly by means of automation and replacing fossil fuel engines. Beside its initial goal of improving ecological sustainability, this project clearly effects social sustainability. An obvious factor is the *Loss of employment opportunities* and *Repositioning* in the area of *Quantitative effects on work*. Furthermore, the current legal situation in Germany does not allow autonomous machines to operate without a supervisor, making the factor *Monotonous and psychologically straining tasks* in the area of *Qualitative effects on work* relevant in this case. MURMEL will perform its task in open public spaces and hence interferes with humans, which should lead to a consideration of both the factors *Ethical complications and responsibility issues* and *Creation of hostile environments*.

After compiling the relevant factors, they must be further specified by defining to what extent they apply to the project. If a possible effect of the implementation is considered to be ‘applicable and urgent’ or ‘applicable’, the according suggestion has to be considered since negative impact on social sustainability is probable. The category ‘not applicable’ implies no significant influence on social sustainability whereas the column ‘not needed (benefit at hand)’ even indicates a potential positive effect.

Figure 3 depicts a first assessment of the project MURMEL in a radar plot. The three different perimeters represent the rating and indicate the applicability or urgency of every given factor from the guideline. ‘Not applicable’ corresponds with the inner perimeter, ‘applicable’ equates to the perimeter in the middle, ‘applicable and urgent’ issues will be plotted on the outer perimeter. If the project is actually promising a beneficial impact, the plot comes to the centre point (as shown in the exemplary implementation for MURMEL for the factor *Dangerous/Physically straining tasks*). As seen in the example on the right, we expect MURMEL to be highly prone to negatively impact the factor *Monotonous and mentally straining tasks*. Overall the urgency to applicate the guideline accords to the size of the grey coloured area in the radar plot: The more it takes up, the more need for action is at hand.

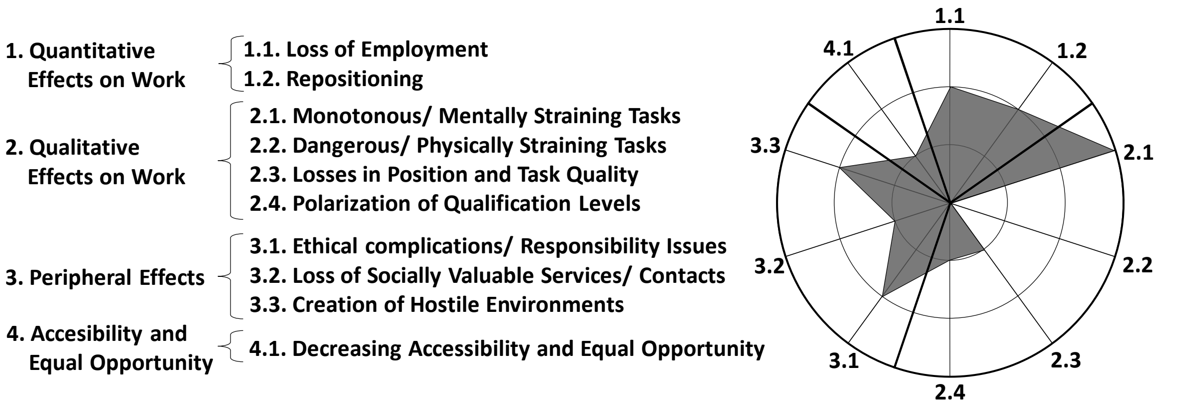

Figure 3. Radar plot to visualize the need for action in an automation initiative

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Following the guideline, we included the suggested procedures into the design process of the service robot. For example, the first two affected areas made us rethink the level of automation and consider an approach of cooperation instead of full automation. Also, the *peripheral effects* underline the importance of social acceptance which can be noticeably improved by implementing a kind of body language and adjusting the outward appearance of the robot (Schneider and Lindau, 2019; Salvini et al., 2010).

7. Conclusions and future work

The main goal of this paper was to create a guideline that accompanies the early design process of automation initiatives and helps to embed social sustainability in their course. To underscore the need for the suggested guideline, we first outlined the current trends in the automation industry, more specifically service robots in an urban environment. Social sustainability should be taken into account, in the concept phase of service robot development. The three dimensions of sustainability are closely intertwined and cannot be considered in isolation. However, this paper focused on the social dimension and only touched upon its interdependencies with the other dimensions. A comprehensive view has yet to be established.

Going further into detail, we defined four areas of the social dimension and worked out a first set of key issues to help classify a given automation project. For each factor a project is to be rated in order to get a feedback on how it fares in terms of social sustainability. The exemplary application for the project MURMEL illustrated the usability of the guideline and our idea of visualizing such a rating. We aimed to create a tool that quickly reveals the impact on social sustainability and acts as a warning system in the early design phases. Additionally, the guideline comprises suggestions to counteract negative effects and provides possible evaluation methods. Applying the guideline, we were able to discover a few weak spots in the concept of MURMEL and we were able to initiate adjustments accordingly.

Considering social sustainability beyond a qualitative approach seems to be a mostly unexplored field of research. With this paper, we pose a methodology to look at this subject in a broader manner. Consequentially, a look into other phases of the product, such as production and recycling, as well as a further investigation into other dimensions of sustainability are not included in this work. We emphasize however that these matters nonetheless have to be addressed in order to achieve a truly and holistically sustainable design. In this regard, we understand this paper as a first contribution specifically to the subject and discussion of social sustainability in automation as well as a supplement to the existing research in the field of SPD. A next step towards an overarching view on this topic could be an examination of ecological and economic sustainability during the use phase and especially how these aspects compete or cooperate regarding the key issues. Furthermore, our proposed guideline is not to be seen as comprehensive and is meant to be extended beyond its current state as an outline of our understanding of social sustainability.

In MURMEL, we include social sustainability goals in the design process of an automation initiative. We identified social key issues and provided a guideline along with measures to counteract potential malpractice. In addition, we discussed evaluation methods, and therefore had to deliberate quantifying social factors and effects. This last thought process in particular is far from complete and calls for new approaches and more research.

In the framework of the project zeroCUTS (MPM TU Berlin, 2019; DFG, 2018) we intend to apply the concept of social sustainability to far reaching automation concepts in the transportation sector, like autonomous shuttle services (Grahle et al., 2020). Applying our guideline to other use cases will help to improve the proposed method in the future.

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