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Shaping the Future of Quality Management – on the way to Quality 4.n

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Abstract: While Industry 4.0 is already significantly changing production processes, the influences on supporting production processes such as quality management are only slowly becoming apparent. In addition, new requirements from the urgent aspect of climate neutrality are added to all processes. While the quality management system according to ISO 9001 is already designed as an integrated management system in connection with ISO 14001 (Environmental management systems) or ISO 51001 (Energy management systems), this is missing for the application-oriented methods which are more important in the context of product development or production development processes. In the context of this contribution, the emerging requirements for quality systems as well as possible solution aspects will be highlighted, which enable an extension of the magic triangle around the topic of sustainability and CO2 reduction for a Quality Approach 4.n. On the one hand, this includes methodological approaches to enable quality and sustainability considerations in integrated method, approaches to optimize production processes of eco-efficient drive systems such as an optimized stacking process for fuel cells based on quality information and approaches for data fusion to collect data from different organizational teams.

Keywords: Quality 4.n, Sustainability

1. Introduction

The organizational anchoring of topic-driven management systems began with the introduction of quality management systems in the late 1980s with the quality management standard ISO 9001 (9001). Originally still primarily activity-focused with the 20 elements, the quality management system changed to a process-oriented approach with the revision of the standard in 2000 (cf. ISO 9001:2000). In addition, derivative standards had been introduced for specific requirements of various industries, such as ISO 13485 for the medical industry or ISO 9100 for the aviation industry. Due to the growing demands on companies, further management systems were developed that address specific areas, such as environmental management systems with ISO 14001, energy management systems with ISO 50001 or, with regard to cyber security, ISO/IEC 27001.

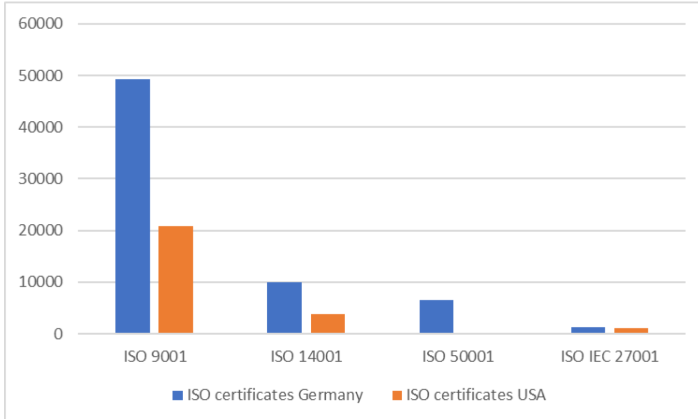

Figure 1. ISO-Certificates 2020 (Note: China has >300000 ISO 9001 and > 150000 ISO 14001 certificates)

In the corporate environment, it has proven useful to combine the various management systems within the framework of an integrated management system (Rebelo, Santos, & Silva, 2016). Especially since the management systems standards developed increased compatibility (Talapatra, Uddin, & Rahman, 2018). Besides the benefit regarding internal resources to have a central unit within the company that takes care of the implementation of and compliance with the standards it ensures that implementations of the standards do not contradict each other, but rather offer a mutual advantage (Talapatra, Santos, Sharf Uddin, & Carvalho, 2019).

The last few years have been marked by disruptive events in companies. The Corona pandemic has led to numerous disruptions in supply chains (Veselovská, 2020), as well as to a large drop in sales due to the changed working conditions and work absences of employees, especially in small and medium-sized companies in Germany (approx. 10% according to a study in 2021 (Lips, Borchardt, Oechsle, Herold, & Groneberg, 2021)). An even more severe crisis began in early 2022 with the military conflict in Ukraine. The further consequences are not yet foreseeable, but the influences on the logistics chains of companies, which can be seen within a very short time, as well as the foreseeable gas (and energy) crisis are immense (Macedonia, 2022; Mbah & Wasum, 2022). However, these influences mask the most relevant challenges facing global society. In order to avert the climate crisis or to keep its effects manageable, it is necessary to significantly reduce the emission of greenhouse gases (Secretariat UNFCCC, 2015). Recent IPCC reports call for immediate action, especially in industrialized nations (IPCC, 2022). After the highest court in Germany, the Federal Constitutional Court German, ruled that the "state's duty of protection arising from Art. 2(2) first sentence of the Basic Law also encompasses the duty to protect life and health against the risks posed by climate" and that the concrete dates and targets set in the law were not sufficient the German parliament adopted the Climate Change Act including a reduction of CO_2 Emissions in 2030 of 65% compared to 1990. Even including the reductions already achieved, the law specify the reductions necessary by each sector as described in Figure 2.

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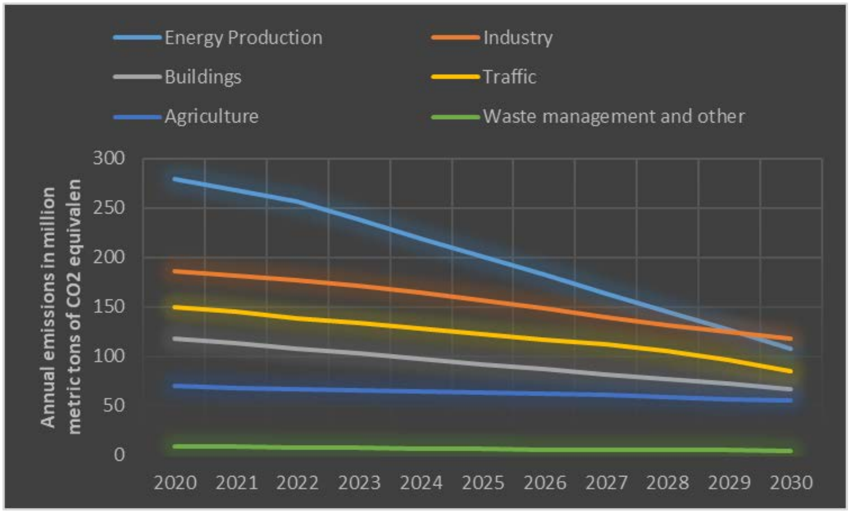

Figure 2. Adopted Climate Change Act (Germany) – annual CO2-equvalent Emissions of sectors up to 2030

For industry, this has several implications. First, direct emissions must be reduced by 60% compared to 1990 levels. In addition, the reduction targets of the other sectors indirectly affect production, as there is a need to switch to other products. In German industry, this primarily affects the automotive sector with the increasing demand for electric vehicles. While in 2020 the share of BEVs (Battery Electric Vehicles) was still at 6.6% of new registrations, in 2021 it was already 13.6% with approx. 355,000 BEVs (Source: Statista.de). In the future, further alternatives with hydrogen-based fuel cells will be added.

2. Derivation of development directions for a future Quality 4.n

While Quality Management, Safety Management, Energy Management and Environmental Management have long since grown together in the Integrated Management Systems (IMS), as mentioned above, there is still a lack of transfer, especially of the environmental aspects, to the operational business units. (Siva, Gremyr, & Halldórsson, 2018). In addition to this aspect, however, the other megatrends and their influence on Quality Management of the future cannot be ignored. This is particularly true of the increasing integration of ICT into corporate processes (Malik & Janowska, 2018). Therefore, we propose four fundamental pillars on which to build the further development of quality management in the coming years:

- Optimization of processes through data analyses incl. use of AI approaches
- Extension and new development of methods for operational support in the development processes
- Support of new products and their production processes
- Ensure the safety and security of the production

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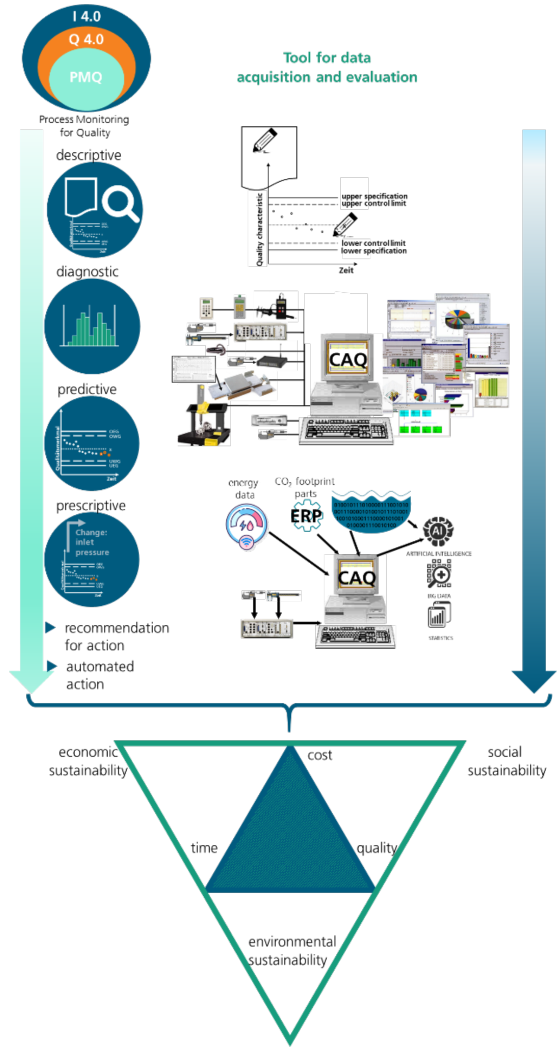

Figure 3. Track to Quality 4.n (In adaption to (Escobar, McGovern, & Morales-Menendez, 2021), (Schmitt et al., 2020))

2.1 Optimization of processes through data analyses incl. use of AI approaches

To reduce scrap and therefore reach a zero waste production regarding quality issues a thoroughly use of Industry 4.0 advantages will be used in production processes. Low cost sensors will be more widely available to support the data gathering (Kalsoom, Ramzan, Ahmed, & Ur-Rehman, 2020) and can also used for retrofitting of existing production lines (Lins, Augusto Rabelo Oliveira, H. A. Correia, & Sa Silva, 2018). Additional advanced analytic options opens up the possibility of achieving the desired quality even with input materials whose specifications are more scattered. Using AI-based models, it is possible not only to derive predictions of various states or outcomes of the product and process, but also to use underlying mathematical algorithms to infer such conclusions that provide specific recommendations for action on control parameters or even initiate and execute them fully automatically. One requirement in the future field of application is the design of such algorithms, which are able to evaluate different multi-criteria result parameters for an overall optimum of economic and ecological benefits such as the CO2 share. For example this could enable the use of recycled plastics in a circular economy approach (Borchardt, Krauß, Lambers, & Schlüder, 2022).

2.2 Extension and new development of methods

Quality management methods are used extensively to ensure product quality in product and process development. Risk management methods in particular have become especially important (Mannuss, Mandel, & Schloske, 2015), not least since the "risk-based thinking" was introduced in the ISO 9001 revision in 2015 (Medic, Karlovic, & Cindric, 2016). Recently, defects that occur in a process step are treated in the FMEA risk analysis in such a way that the combination of defect probability and defect detection, the resulting slip is used as an input variable of probability into the subsequent process.

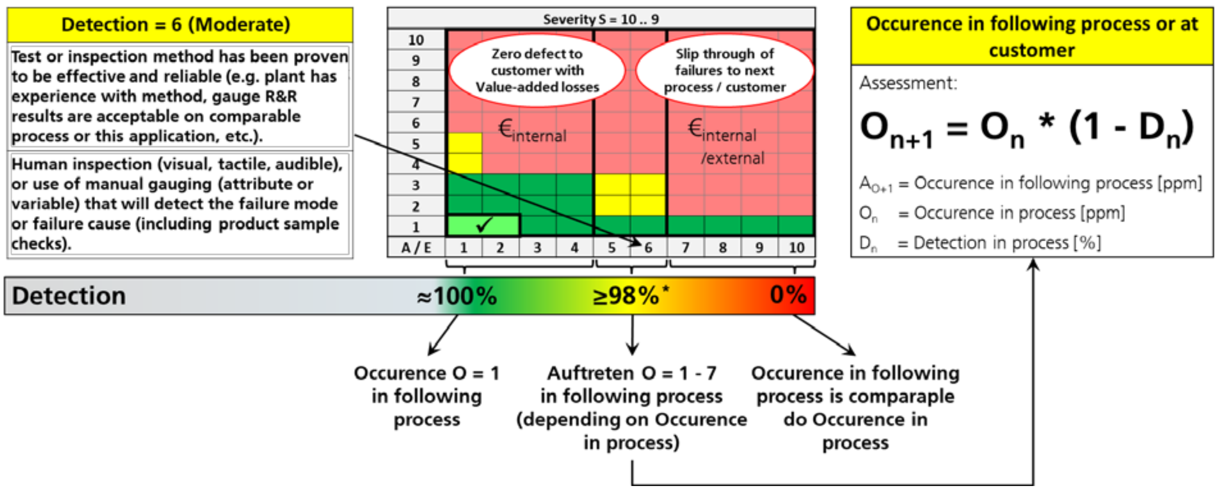

Figure 4. Assessment of Failure propagation in following processes (with new Evaluation tables according to VDA/AIAG 2019 (AIAG/VDA, 2019))

But as stated by Siva (Siva et al., 2016) “it is necessary to develop and adapt the tools and practices, rather than apply them as they are”. In order to address this, proven methods should be examined to determine the extent to which an expansion of the scope of consideration is possible. It should be noted, however, that the application of the methodology should not become significantly more extensive and complicated. Ideally, only a few additional pieces of information or assessments would lead to an additional broadening of the perspective to other sustainability goals. An example of this is the adaptation of the Failure Process Matrix (Schloske & Henke, 2006) to include aspects of environmental sustainability. In this case, the waste of CO_2 due to potential production defects is additionally determined in addition to the defect considerations with the extended view of the detection distance and the monetary aspects already covered (and thus economic sustainability). For a more detailed description see Garcia (Garcia, Borchardt, Mannuss, & Lips, 2022).

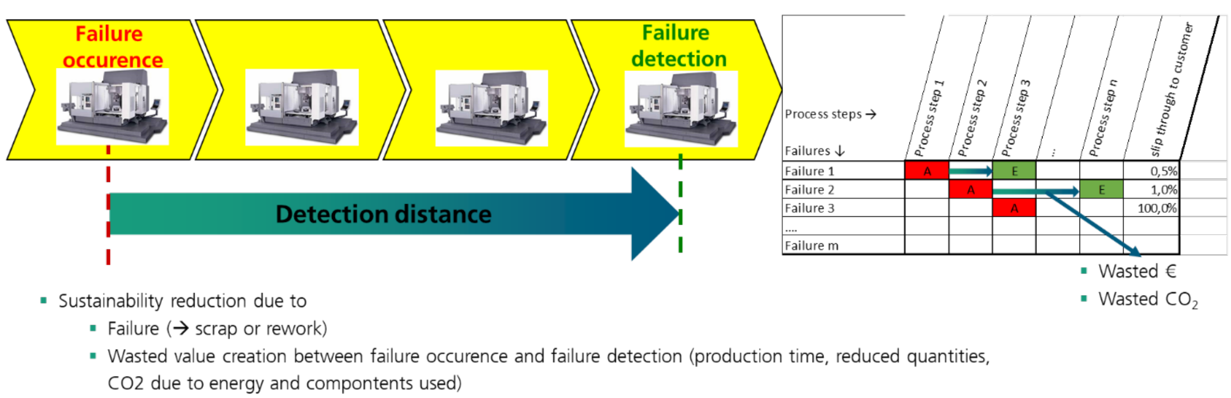

Figure 5. Adapted Failure Process Matrix as an example to enhance quality methodologies to additionally address sustainability goals

2.3 Support of new products and their production processes

Several new products had been or will be introduced to support the CO_2 reduction. For the automotive sector, the transformation to electric vehicles is a major shift in existing production structures. For the Quality Management it is particularly important to support the change process. A core concern of Quality 4.n is, on the one hand, to ensure stable and reproducible processes, which, on the other hand, make it possible to produce a reused, equivalent product with the same quality characteristics and lifetime properties as a new product. The challenge of this transformation process in terms of sustainability and resource efficiency is that the use of energy and other resources should result in an improved environmental and CO_2 footprint. In addition to social sustainability in the procurement and provision of the necessary resources (cf. Act on Corporate Due Diligence in Supply Chains), key aspects are the impact on people, machines and the environment during the ongoing production and operational processes. One example to enhance the contribution to sustainability goals is the approach for disassembly of traction batteries for reuse purposes (Gloeser-Chahoud et al., 2021) (Baazouzi, Weeber, & Birke, 2022) (Al Assadi et al., 2022). To ensure the social sustainability, focused risk management procedures as well as technical risk mitigation measures will be necessary (Mannuss, 2021).

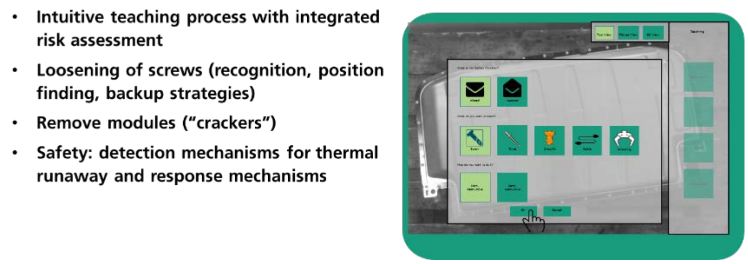

Figure 6. Risk assessment during teaching process for the disassembly of a new traction battery variant

2.4 Ensure the safety and security of the production

Safety and Security for the new smart production scenarios will be a main topic (Anderl, 2014; Kloibhofer, Kristen, & Jakšić, 2018). The increasing complexity and sophistication of production processes, the permanently advancing digitalization and, above all, networking inevitably also lead to more complex scenarios for the vulnerability and thus requirements for the resilience of highly modern and -automated production processes. With the increase of AI-based methods, human-machine interaction is further intensified. New approaches needs to be derived to ensure worker safety and compliance with regulatory demands in the permanently changing production circumstances (Siegert et al., 2021). Safety risks can also be caused by cyberattacks into a production system. On the one hand, this can endanger the workers in the factory. In addition, it is conceivable that unnoticed changes to process specifications of machines and systems in the production process may mean that the specifications of safety-relevant features can no longer be met, thus end customers may be at risk.

3. Conclusions

To achieve sustainability and the global climate goals Quality Management needs adaption in the upcoming years. Besides recent achievements to address the proposed trends, future works will be necessary to address the changes in usable approaches.

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