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# Identification of Human and Organizational Key Design Factors for Digital Maturity – A Fuzzy-Set Qualitative Comparative Analysis

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**Abstract**

This paper examines how human and organizational factors need to be designed to achieve strong technological maturity of either the products or the production process. In a fuzzy-set qualitative comparative analysis (fs/QCA), a combination of intensive training and strong worker participation is found to be associated with strong technological maturity in the two organizational contexts: firms with a strong entrepreneurial culture and in large firms oriented towards customer-oriented innovation. Overall, the paper uncovers designs or causal recipes for a successful digital transformation.

*Keywords: human-centred design, industry 4.0, performance indicators, digital maturity*

## 1. Introduction

Most firms are grappling with "digital transformation", the use of digital technologies to create benefits along the entire value chain, and are striving for "digital maturity", the desired endpoint of digital transformation (Appelfeller and Feldmann, 2018; Steiber et al., 2021). In order to benchmark their achievement, firms often participate in digital maturity models. They measure, via questionnaire surveys among decision-makers, numerous indicators of human, organizational and technology dimensions of a firm's degree of digitalization (Berghaus and Back, 2016; Teichert, 2019). In this paper, we re-analyse the data of a particular digital maturity model applying a design-oriented empirical method, namely fs/QCA – fuzzy-set qualitative comparative analysis (Ragin, 2000, 2008). We find that the outcome of a firm's strong technological maturity often results from two success paths: **intensive training and strong worker participation need to be combined either with a strong entrepreneurial culture or with strongly customer-oriented innovation in larger firms.** Overall, this paper responds to the fact that decision-makers as well as researchers are overwhelmed by the "multifaceted complexity" of digital maturity (Park et al., 2020) – numerous factors matter, and the success paths differ depending on firm size and other organizational influences (Buer et al., 2021; Teo and King, 1997). The two frequent designs found in this paper suggest that firms do not need to achieve maturity in each and every dimension discussed in digital maturity models.

## 2. State of the art

**Socio-technical system perspective:** A successful digital transformation cannot be realized solely by introducing innovative technologies and embedding them in the technical infrastructure. Employee skills, processes and the underlying corporate structure must also be adapted to digitalization. Digital transformation is therefore understood as a socio-technical challenge (Schnasse et al., 2020). Hobscheidt et al. (2020) suggest a framework with various factors divided into three socio-technical dimensions.

The human dimension consists in qualification, work tasks, collaboration and work structures; the organization dimension in culture, processes and organization as well as knowledge; and the technology dimension in automation, IT systems and data management. According to the socio-technical understanding of systems, these dimensions and factors must be coordinated synergistically and considered in equal measure in order to ensure the beneficial operation of digital technologies (Hobscheidt et al., 2020). This implies that **all factors need to be present for a company to achieve digital maturity**. This strong, **maximalist hypothesis** has been criticized. (Pöppelbuß and Röglinger, 2011). It is unlikely that firms will achieve full maturity on all counts of the socio-economic framework. It has been argued that multiple routes to digital transformation are possible and that these success paths differ by firm size as well as other organizational and strategic factors (Buer et al., 2021; Eller et al., 2020; Horváth and Szabó, 2019; Pöppelbuß and Röglinger, 2011; Teo and King, 1997). Furthermore, some factors matter more than others. Human resource factors that secure employees skills' and their acceptance are considered key aspects (Kane, 2019; Arendt, 2008; Erol et al., 2016; Horváth and Szabó, 2019). Success paths also depend on whether a company's process or its products and services are to be digitalized (Lipsmeier, 2021).

There are numerous measurement models, termed **digital maturity models**, based on questionnaire surveys among decision-makers in firms. The models assess a firm's current state of digital maturity and benchmark it against other firms and a target state. This comparison serves to uncover weaknesses and to identify the relevant fields of action for digitalization (Berghaus and Back, 2016; Teichert, 2019; Schuh et al., 2020; Knospe et al., 2018). Most of these models reflect the maximalist hypothesis mentioned above. Recent work, however, develops specific digital maturity models adapted to particular contexts of industry or company size (Becker et al., 2009).

**In sum,** the literature agrees that digital transformation exposes firms to a complex challenge involving multiple human, organizational and technological factors. The maximalist hypothesis, according to which firms need to perform equally across all factors, has been considered unrealistic. It is more likely that multiple paths to digital maturity will be successful but the literature has only begun to identify the success paths that different types of firms adopt as appropriate.

## 3. Conceptual Framework

### 3.1. A multiplicity approach

This paper adopts the multiplicity framework developed by Park et al. (2020). The multiple factors involved in digital transformation are covered by different theories; this is what Park et al. (2020) term "theoretical multiplicity". In addition, these factors often interact in complex ways in bringing about digital maturity, a situation the authors call "configurational multiplicity". For example, human and organizational capital are argued to be mutually reinforcing in supporting the digitalization process (Schneider, 2018). The multiplicity framework suggests fs/QCA as an analytic method. The fs/QCA method examines on real-world data how an outcome is brought about by a number of conditions (Ragin, 2008). The method is better suited than statistical models to come to grips with complexity and multiplicity (Park et al., 2020; Fiss, 2011; Misangyi et al., 2017; Ragin, 2008). **Specifically, this paper asks: Which combinations of factors bring about digital technological maturity and which factors do not count at all?** In Section 3.2, technological maturity is defined in two dimensions and these are suggested as the outcome of digital transformation that need to be explained. In Section 3.3, the most important factors that likely contribute to lead to technological maturity are identified. Finally, in Section 3.4, it is speculated how the conditions combine to bring about the outcome.

### 3.2. Outcomes to be explained

A successful digital transformation means that companies have adopted advanced digital technologies and have integrated them successfully into their operations. Hence, the measure of digital maturity that is to be explained is a company's strong technological maturity. It is important to distinguish between two different areas in which firms can adopt such technologies (Lipsmeier, 2021).



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***Technological maturity of products*** (PRODUCT): Digital transformation offers a large potential for increasing the utility of products. The digital maturity of a product is characterized by various criteria. For example, a digital product is capable of collecting data via sensors, influencing physical processes via actuators and independently processing information between sensors and actuators. Such technologies are termed "cyber-physical systems", defined as open socio-technical systems that use globally available data and services and are controlled via multimodal human-machine interfaces (Geisberger and Broy, 2012; Kagermann et al., 2013).
***Technological maturity of production*** (PRODUCTION): The solutions of digitalization unleash their productivity-enhancing effect primarily in production processes. The digital maturity of production is characterized by a variety of criteria. These include the networking of processes and resources along the internal and external value chain, the linking of technical processes with business processes, digitalization of development processes along the value chain and the degree of interaction between humans and machines. The extent to which internal production is digitized also depends on the type and scope of operational data collected and the use of assistance systems in production (Kagermann et al., 2013).

## 3.3. The factorial logic: Key explanatory factors

The socio-technical framework distinguishes organizational and human factors, in line with the idea that organizational and human capital are restraining factors for the successful implementation of digital technology (Brynjolfsson and McAfee, 2014). Importantly, organizational factors refer to strategic properties and organizational contexts that may be more or less supportive for digital transformation; they can be considered remote conditions, which cannot be changed easily in the short run (Schneider and Wagemann, 2006). Human factors such as skills and work practices can be considered proximate conditions; they are closer to the outcome to be explained (Schneider and Wagemann, 2006). Especially non-tayloristic or "holistic" work practices have been described as complementary to digital transformation (Schneider, 2018; Lindbeck and Snower, 2000).

### Organizational factors

***Company size*** (SIZE) is a major organizational factor. Studies show that smaller companies have a lower level of digital maturity on average (OECD, 2021). Reasons for this often include a lack of internal resources, a lack of awareness, skill gaps, or funding issues. In order to identify and overcome these hurdles, some research focuses on the digitalization of small and medium-sized enterprises (Eller et al., 2020; Bouwman et al., 2019; Arendt, 2008) and some digital maturity models are explicitly aimed at these enterprises (Kuusisto et al., 2021; Virkkala et al., 2020; Kljajić Borštnar and Pucihar, 2021).
The substance of a ***customer-oriented innovation strategy*** (CO-INNOVATION) is to perform "innovation with customers" (Desouza et al., 2008). Customers are involved in the process to better meet their requirements and integrate them quickly. The focus on the consumer is considered a decisive strategy for success in times of digital transformation (Goran et al., 2017).
***Entrepreneurial culture*** (E-SPIRIT): Entrepreneurial culture is part of the corporate culture. In companies with an offensive innovation strategy, the culture is characterized, for example, by a high level of intrinsic motivation among employees and a management style with an error-forgiving culture. This type of culture or spirit is considered to be particularly conducive to innovation and thus promising in times of digital transformation (Schaefer et al., 2017).

### Human factors

Lindbeck and Snower (2000) termed "holistic" work practices as indicating a move away from tayloristic work. Holistic work is more varied, employees receive more training, they are able to participate in traditionally managerial decisions and they are more autonomous in organizing their own work. Each of these practices has been considered as conducive to digital transformation (Schneider, 2018).
***Job autonomy*** (AUTONOMY) represents an opportunity for employees to organize their work independently. Autonomous employees are allowed to shape time planning, to choose work tools and



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procedures and to make decisions without consulting management. A high level of employee autonomy might exert a positive effect on digitalization processes, as it promotes acceptance of change processes (Gagne et al., 2000).

***Participation*** (PARTICIPATION) refers to opportunities for workers to actively participate in shaping work-related processes. Motivation through participation helps to overcome defensive forces such as resistance against introducing new technologies and the associated adaptation of work processes (Gagne et al., 2000). Involving employees requires considerable trust on the part of the employer but is connected with better engagement (Wohlgemuth et al., 2019). Organizations with highly engaged employees experience increased customer satisfaction, profits and employee productivity (Osborne and Hammoud, 2017).

***Training*** (TRAINING) is one of the most important means of adapting employees' skills to the changed working conditions and tasks resulting from digitalization (OECD, 2019; Janssen et al., 2018). Companies with systematically designed and regular training programs can thus be superior to companies with isolated and unsystematic training concepts when it comes to digitalization.

***Variety*** (VARIETY) refers to the degree to which employees conduct more than one task. A high degree of job variety is also likely to increase technological maturity at the firm level (Lindbeck and Snower, 2000). Employees with more varied jobs are familiar with the process and are able to contribute to implementing new technology.

### 3.4. The combinatorial logic: Causal recipes as combinations of conditions

The fs/QCA examines multiplicity by identifying necessary and sufficient conditions. Usually, not a single condition but a combination of conditions is found to be sufficiently linked to an outcome. **Sufficiency** means: When the combination is present, the outcome will also be present. The maximalist hypothesis of digital maturity models implies that each and every condition needs to be present for a positive outcome to occur. In other words, the only combination sufficient for technological maturity involves the presence of all causal conditions. The maximalist approach also implies that each and every conditions alone will be necessary. **Necessity** means: When the outcome is present, the condition will also be present. Overall, there seems to be only one success path to strong technological maturity involving the presence of all conditions.

Such strong synergies are unlikely to hold, as Section 2 has illustrated. Then, more than one combination of conditions or success path will exist for each outcome, and each will consist of a limited number of conditions while other conditions are irrelevant for bringing about the outcome. Given the number of conditions and two outcomes, it is almost impossible to formulate exact theoretical expectations. Hence the analysis in this paper is abductive (Park et al., 2020). Based on the factors we have identified, the fs/QCA yields empirical patterns of sufficiency. These will be used to formulate a new hypothesis that elaborates on, and possibly deviates from, the maximalist benchmark hypothesis.

**In sum, the conceptual framework** differs from the way in which digital maturity models have been utilized in the past. First, rather than treating the factors as equivalent components of digital maturity, a causal link between the factors is assumed: some organizational factors along with human factors bring about technological maturity. Second, the method of fs/QCA is applied to identify multiple successful paths to technological maturity, each consisting of a limited number of organizational and human factors.

## 4. Methods

### 4.1. Data and the fs/QCA analytic

Data from one particular digital maturity model was re-analysed for the purpose of this paper. The data come from a questionnaire survey that had been set up in the context of the research project INLUMIA – Instruments for Improving the Performance of Companies through Industry 4.0 was re-analysed (Knospe et al., 2018). In INLUMIA, a questionnaire survey had been implemented on the project's homepage and distributed at various events in the course of the project. It was taken by approximately 150 respondents who worked in German companies from various sectors with a clear majority in manufacturing. Of these, 109 questionnaires were available for analysis for this paper. A total of 33 indicators, each comprising four levels, were included in the survey to measure digital maturity.

The fs/QCA method is based on **set theory and Boolean algebra** and proceeds through various stages, which cannot be fully explained here but are described at length in standard textbooks (Ragin, 2008; Schneider and Wagemann, 2012). First, raw values are "calibrated" into fuzzy-set values ranging from 0 to 1. Second, necessary conditions are analysed. A condition is necessary when, for each case (i.e. for each firm), the value of the condition exceeds or is equal to the value for the outcome. Third, a truth table is set up. It consists for each condition of crisp-set values, i.e. the values of 1 and 0 indicating whether element is more a member of a set or not. The combination of crisp-set conditions define a number of ideal types. Fourth, based on the truth table, a sufficiency analysis is conducted. Sufficiency means that the fuzzy-set value of the outcome is larger than or at least equal to the fuzzy-set value of the condition. This must be true for all (or in practice, most) empirical cases. The fuzzy-set value for each case in each condition is given by the minimum of all fuzzy-set values across all conditions of an ideal type. Fifth, the Boolean expression of ideal types that are found to be sufficient is minimized to a shorter expression. The resulting expression usually includes multiple combinations of conditions, each of which represents one success paths to the outcome.

In the conceptual framework, organizational factors were considered as remote conditions, and human factors as proximate conditions. Both types of factors were analysed in separate fs/QCA models, adopting the two-step approach developed by Schneider and Wagemann (2006). In a first step, the three organizational or remote conditions were included in an fs/QCA. This yielded two combinations that tend to sufficiently explain the outcome. The observed cases with positive fuzzy-set values in these combinations were then retained for analysis in the second step: an fs/QCA with the four work practices considered as proximate conditions.

### 4.2. Measures and calibration

The calibration process was conducted following standard procedures (Ragin, 2008). Setting the crossover point 0.5 is essential: Cases with values above 0,5 are considered as cases more in than out of the set. For example, a fuzzy-set value of 0.6 for a particular firm's technological maturity of products implies that the firm achieved considerable though not full maturity.

For the two outcomes, the raw data consisted of multiple single items each measured on four-point scales. The mean of the values were taken and then calibrated applying the so-called direct method (Ragin, 2008, pp. 87–94). Here a curvilinear relation between raw values and fuzzy-set values is derived. The shape of the function is defined by three anchors: raw values that indicate full non-membership and full membership in the set as well as a crossover point. For the two outcomes ranging from values of 1 to 4, the anchors were set at 1.5, 2.9 and 2.0, respectively. A crossover point at 2.0 implies that a firm was considered technologically more mature than not when it achieved a value of 3 (out of 4) in at least one of the items included in the multi-item measure. Setting a higher crossover point would be inappropriate because the value of 4 described an end state of digital transformation which hardly any firm acquired already. Other digital maturity models are defined on a five-point scale (Kagermann et al., 2013); the calibration chosen here is roughly equivalent to a value of around 3 in that scale. The value representing the existence of digital maturity must therefore be selected on a case-by-case basis, taking into account the scale of the maturity model used.

Calibration of the seven conditions differed from that of the outcomes. Raw data for each condition was defined by a single item ranging 1 to 4. The values were calibrated in a straightforward way such that a raw value of 1 was assigned a value of 0.0, 2 was assigned a 0.25, 3 was assigned a 0.75, and 4 was assigned a 1.0. This implied that conditions were calibrated slightly more strictly than the outcomes. If we compare our measurement of conditions to the maturity model of (Kagermann et al., 2013), the values of 0.75 and 1 are more or less equivalent to the values of 4 and 5 in that model.

## 5. Findings

### 5.1. Analysis of necessity and sufficiency

In the necessity analysis, none of the seven conditions was found to be necessary for strong technological maturity in either of the two outcomes. This is an important finding that contradicts the maximalist hypothesis, which claims that all conditions should be necessary.



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In a first step of the sufficiency analysis in fs/QCA, it was analysed how the two outcomes are related to the three remote conditions. The analysis yielded two organizational contexts in which firms often achieve technological maturity. A strong entrepreneurial spirit (E-SPIRIT) alone was found to be sufficient for technological maturity. Similarly, large firms that strongly pursue customer-oriented innovation (SIZE combined with CO-INNOVATION) also describe a combination sufficient for technological maturity. This finding is identical for both outcomes, and 43 out of the 109 firms share one of these organizational contexts or both.

In a second step, these 43 cases were analysed in an fs/QCA with four holistic work practices as conditions. The findings are summarized in figure 1 and 2.[1]

| Presence, Absence and Irrelevance of conditions for each success path to reach digital maturity of **products.** | | Digital maturity of products | |
|---|---|---|---|
| | | Success path 1 | Success path 2 |
| Human conditions | Autonomy | | ✓ |
| | Participation | ✓ | ✗ |
| | Training | ✓ | ✓ |
| | Variety | | |
| Number of covered firms | | 11 | 3 |

✓: Presence of a condition; ✗: Absence of a condition;
Empty Cell: Irrelevance of a condition

**Figure 1. Second-step solution for outcome digital maturity of the products**

| Presence, Absence and Irrelevance of conditions for each success path to reach digital maturity of **production.** | | Digital maturity of production | | | | |
|---|---|---|---|---|---|---|
| | | Success path 1 | Success path 2 | Success path 3 | Success path 4 | Success path 5 |
| Human conditions | Autonomy | | | ✓ | ✗ | ✓ |
| | Participation | ✓ | | | ✓ | ✓ |
| | Training | ✓ | ✓ | | | ✗ |
| | Variety | | ✗ | ✗ | ✓ | |
| Number of covered firms | | 11 | 5 | 4 | 2 | 3 |

✓: Presence of a condition; ✗: Absence of a condition;
Empty Cell: Irrelevance of a condition

**Figure 2. Second-step solution for the outcome digital maturity of the production**

[1] All calculations were made with the QCA package for R provided by Dușa (2018) and followed the state-of-the art protocol summarized in Schneider and Wagemann (2012). Truth tables, details of model choice and goodness of fit cannot be reported here for lack of space but will be provided by the authors on request.



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For the outcome of technological maturity of products, two success paths emerged. Path 1 contains firms with strong PARTICIPATION and strong TRAINING. This combination was found to be sufficient for the outcome, whereas AUTONOMY and VARIETY were found to be irrelevant. Hence, even with low levels of these latter conditions, firms may achieve strong technological maturity of products. Success path 1 is followed by 11 out of 43 firms included in the analysis. Success path 2 only covers 3 firms. It combines strong TRAINING and strong AUTONOMY with the absence of strong PARTIPATION, with VARIETY being irrelevant.
Findings for strong technological maturity of production, reported in Figure 2, are more varied suggesting five different success paths. The paths 2 to 5 are highly divergent and each cover 2 to 5 firms only. Success path 1 covers 11 firms and is identical with success path 1 in Figure 1. Hence, (PARTICIPATION combined with TRAINING) was found to be successful for both outcomes of technological maturity given the supportive organizational circumstances.

## 5.2. From a maximalist to a new hypothesis

Both the analysis of necessity and of sufficiency in the previous section provides strong evidence against the maximalist hypothesis. None of the conditions was found necessary. Furthermore, a whole range of combinations of conditions was found to be sufficient for technological maturity. The many success paths uncovered by the fs/QCA findings differed strongly, and they cannot all be summarized in a simple new hypothesis or clear recipe for firms. However, in terms of frequency, the fs/QCA has produced a key finding that can be summarized in a new hypothesis: Firms with favourable organizational conditions (SIZE combined with CO-INNOVATION; or E-SPIRIT) often show high technological maturity – but only when they also invest in training and at the same time grant their employees strong participation. It is plausible that (PARTICIPATION combined with TRAINING) is often involved in successful digital transformation: The combination indicates that a firm prepares their employees for digital transformation by enhancing their skills (through training) and by granting them opportunities to apply their skills and contribute to the digital transformation process (through participation). These practices apparently matter more for a successful digital transformation than the design of particular jobs, which is covered by the two less important practices VARIETY and AUTONOMY.
**To summarize the main findings of the paper,** Figure 3 juxtaposes the maximalist hypothesis with this new hypothesis represented by success paths 1 and 2.

| Presence, Absence and Irrelevance of conditions for the maximalist hypothesis (theory) compared to identified success paths (findings) to reach digital maturity of **production and product.** | | Digital maturity of production and product | | |
|---|---|---|---|---|
| | | Maximalist Hypothesis (theory) | Success path 1 (findings) | Success path 2 (findings) |
| Human conditions | Autonomy | ✓ | | |
| | Participation | ✓ | ✓ | ✓ |
| | Training | ✓ | ✓ | ✓ |
| | Variety | ✓ | | |
| Organizational conditions | Company size | ✓ | | ✓ |
| | Customer-oriented innovation strategy | ✓ | | ✓ |
| | Entrepreneurial culture | ✓ | ✓ | |

✓: Presence of a condition; ✗: Absence of a condition;
Empty Cell: Irrelevance of a condition

**Figure 3. Maximalist vs. new hypothesis for successful digitalization of the product and production**



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Note that the maximalist hypothesis does not contradict the new one. The maximalist solution term in Figure 3 is a subset of both success path 1 and of 2 in the new hypothesis. In other words: When all organizational and human factors are present, this will be sufficient for a positive outcome but firms do not need to adopt all seven organizational and human factors.

## 6. Conclusions

The paper started out with a maximalist hypothesis, in which each and every organizational and human factor needs to be present. In light of the paper, the hypothesis should be overcome by a view in which firms can transform themselves to digital maturity through strongly divergent paths. The most frequents paths were summarized in a new hypothesis, from which several implications follow. For example, smaller firms can achieve technological maturity when they practice a strong entrepreneurial culture. Furthermore, intensive training and strong employee participation are frequently combined in firms achieving technological maturity.
This paper focused on one particular digital maturity model. Future studies should extend the analysis to other such benchmarking studies from heterogeneous contexts and with possibly larger sample sizes. An extended analysis could help to test and further elaborate the new hypothesis presented in this paper. The multiplicity framework including the fs/QCA has proved to be highly suitable for the empirical analysis; it can act as an analytic funnel to identify key factors and their combinations. Future studies should also focus on longitudinal analysis as well as data involving various informants and combining firm- and worker-level information. This is because the cross-sectional INLUMIA data are based on information from one respondent and therefore did not allow us to establish whether the key design elements really cause technological maturity.

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### References

Appelfeller, W. and Feldmann, C. (2018), Die digitale Transformation des Unternehmens, Springer Berlin Heidelberg, Berlin, Heidelberg. https://doi.org/10.1007/978-3-662-54061-9.

Arendt, L. (2008), “Barriers to ICT adoption in SMEs: how to bridge the digital divide?”, Journal of Systems and Information Technology, Vol. 10 No. 2, pp. 93–108. https://doi.org/10.1108/13287260810897738.

Becker, J., Knackstedt, R. and Pöppelbuß, J. (2009), “Developing Maturity Models for IT Management”, Business & Information Systems Engineering, Vol. 1 No. 3, pp. 213–222. https://doi.org/10.1007/s12599-009-0044-5.

Berghaus, S. and Back, A. (2016), “Stages in Digital Business Transformation. Results of an Empirical Maturity Study”, MCIS 2016 Proceedings, No. 22.

Bouwman, H., Nikou, S. and Reuver, M. de (2019), “Digitalization, business models, and SMEs: How do business model innovation practices improve performance of digitalizing SMEs?”, Telecommunications Policy, Vol. 43 No. 9, p. 101828. https://doi.org/10.1016/j.telpol.2019.101828.

Brynjolfsson, E. and McAfee, A. (2014), The second machine age: Work, progress, and prosperity in a time of brilliant technologies, WW Norton & Company.

Buer, S.-V., Strandhagen, J.W., Semini, M. and Strandhagen, J.O. (2021), “The digitalization of manufacturing: investigating the impact of production environment and company size”, Journal of Manufacturing Technology Management, Vol. 32 No. 3, pp. 621–645. https://doi.org/10.1108/JMTM-05-2019-0174.

Desouza, K.C., Awazu, Y., Jha, S., Dombrowski, C., Papagari, S., Baloh, P. and Kim, J.Y. (2008), “Customer-Driven Innovation”, Research-Technology Management, Vol. 51 No. 3, pp. 35–44. https://doi.org/10.1080/08956308.2008.11657503.

Eller, R., Alford, P., Kallmünzer, A. and Peters, M. (2020), “Antecedents, consequences, and challenges of small and medium-sized enterprise digitalization”, Journal of Business Research, Vol. 112, pp. 119–127. https://doi.org/10.1016/j.jbusres.2020.03.004.

Erol, S., Jäger, A., Hold, P., Ott, K. and Sihn, W. (2016), “Tangible Industry 4.0: A Scenario-Based Approach to Learning for the Future of Production”, Procedia CIRP, Vol. 54, pp. 13–18. https://doi.org/10.1016/j.procir.2016.03.162.
Fiss, P.C. (2011), “Building Better Causal Theories. A Fuzzy Set Approach to Typologies in Organization Research”, Academy of Management Journal, Vol. 54 No. 2, pp. 393–420. https://doi.org/10.5465/amj.2011.60263120.
Gagne, M., Koestner, R. and Zuckerman, M. (2000), “Facilitating Acceptance of Organizational Change: The Importance of Self-Determination1”, Journal of Applied Social Psychology, Vol. 30 No. 9, pp. 1843–1852. https://doi.org/10.1111/j.1559-1816.2000.tb02471.x.
Geisberger, E.M. and Broy, M. (2012), “agendaCPS – Integrierte Forschungsagenda Cyber-Physical Systems”.
Goran, J., LaBerge, L. and Srinivasan, R. (2017), “Culture for a digital age”, McKinsey Quarterly.
Hobscheidt, D., Kühn, A. and Dumitrescu, R. (2020), “Development of risk-optimized implementation paths for Industry 4.0 based on socio-technical pattern”, Procedia CIRP, Vol. 91, pp. 832–837. https://doi.org/10.1016/j.procir.2020.02.242.
Horváth, D. and Szabó, R.Z. (2019), “Driving forces and barriers of Industry 4.0: Do multinational and small and medium-sized companies have equal opportunities?”, Technological Forecasting and Social Change, Vol. 146, pp. 119–132. https://doi.org/10.1016/j.techfore.2019.05.021.
Janssen, S., Leber, U., Arntz, M., Gregory, T. and Zierahn, U. (2018), Betriebe und Arbeitswelt 4.0: Mit Investitionen in die Digitalisierung steigt auch die Weiterbildung, IAB-Kurzbericht (accessed 26 February 2020).
Kagermann, H., Wahlster, W. and Helbig, J. (2013), “Recommendations for implementing the strategic initiative INDUSTRIE 4.0. Final report of the Industrie 4.0 Working Group”, available at: https://www.acatech.de/publikation/umsetzungsempfehlungen-fuer-das-zukunftsprojekt-industrie-4-0-abschlussbericht-des-arbeitskreises-industrie-4-0/download-pdf?lang=wildcard.
Kane, G. (2019), “The Technology Fallacy. People are the real key to digital transformation”, Research-Technology Management, Vol. 62 No. 6, pp. 44–49. https://doi.org/10.1080/08956308.2019.1661079.
Kljajić Borštnar, M. and Pucihar, A. (2021), “Multi-Attribute Assessment of Digital Maturity of SMEs”, Electronics, Vol. 10 No. 8, p. 885. https://doi.org/10.3390/electronics10080885.
Knospe, O., Drewel, M., Mittag, T., Pierenkemper, C. and Hobscheidt, D. (2018), “Leistungssteigerung durch Industrie 4.0 für kleine und mittlere Unternehmen”, Zeitschrift für wirtschaftlichen Fabrikbetrieb, Vol. 113 No. 1-2, pp. 83–87. https://doi.org/10.3139/104.111867.
Kuusisto, O., Kääriäinen, J., Hänninen, K. and Saarela, M. (2021), “Towards a Micro-Enterprise–Focused Digital Maturity Framework”, International Journal of Innovation in the Digital Economy, Vol. 12 No. 1, pp. 72–85. https://doi.org/10.4018/IJIDE.2021010105.
Lindbeck, A. and Snower, D.J. (2000), “Multitask Learning and the Reorganization of Work: From Tayloristic to Holistic Organization”, Journal of Labor Economics, Vol. 18 No. 3, pp. 353–376. https://doi.org/10.1086/209962.
Lipsmeier, A. (2021), “Systematik zur Entwicklung von Digitalisierungsstrategien für Industrieunternehmen”, Dissertation, Fakultät für Maschinenbau, Universität Paderborn, Paderborn, 2021.
Misangyi, V.F., Greckhamer, T., Furnari, S., Fiss, P.C., Crilly, D. and Aguilera, R. (2017), “Embracing Causal Complexity. The Emergence of a Neo-Configurational Perspective”, Journal of Management, Vol. 43 No. 1, pp. 255–282. https://doi.org/10.1177/0149206316679252.
OECD (2019), Getting Skills Right: Future-Ready Adult Learning Systems, OECD Publishing. https://doi.org/10.1787/9789264311756-en.
OECD (2021), The Digital Transformation of SMEs, OECD Studies on SMEs and Entrepreneurship, OECD Publishing, Paris. https://doi.org/10.1787/bdb9256a-en.
Osborne, S. and Hammoud, M.S. (2017), “Effective Employee Engagement in the Workplace”, International Journal of Applied Management and Technology, Vol. 16 No. 1. https://doi.org/10.5590/IJAMT.2017.16.1.04.
Park, Y., Fiss, P.C. and El Sawy, O.A. (2020), “Theorizing the Multiplicity of Digital Phenomena: The Ecology of Configurations, Causal Recipes, and Guidelines for Applying QCA”, MIS Quarterly, Vol. 44 No. 4, pp. 1493–1520. https://doi.org/10.25300/MISQ/2020/13879.
Pöppelbuß, J. and Röglinger, M. (2011), “What makes a useful maturity model? A Framework of general design principles for maturity models and its demonstration in business process management”, ECIS 2011 Proceedings, No. 28.
Ragin, C.C. (2000), Fuzzy-set social sciences, University of Chicago Press, Chicago.
Ragin, C.C. (2008), Redesigning social inquiry: Fuzzy sets and beyond, University of Chicago Press, Chicago.
Schaefer, D., Bohn, U. and Crummener, C. (2017), Culture First!: Von den Vorreitern des digitalen Wandels lernen Change Management Studie 2017, München.

Schnasse, F., Menzefricke, J.S., Gabriel, S., Hobscheidt, D., Parlings, M., Kühn, A. and Dumitrescu, R. (2020), Identification of sociotechnical changes caused by Industry 4.0. https://doi.org/10.15480/882.3132.
Schneider, C.Q. and Wagemann, C. (2006), "Reducing complexity in Qualitative Comparative Analysis (QCA): Remote and proximate factors and the consolidation of democracy", European Journal of Political Research, Vol. 45 No. 5, pp. 751–786. https://doi.org/10.1111/j.1475-6765.2006.00635.x.
Schneider, C.Q. and Wagemann, C. (2012), Set-Theoretic Methods for the Social Sciences, Cambridge University Press, Cambridge. https://doi.org/10.1017/CBO9781139004244.
Schneider, M. (2018), "Digitalization of Production, Human Capital, and Organizational Capital", in Harteis, C. (Ed.), The Impact of Digitalization in the Workplace: An Educational View, Springer International Publishing, Cham, pp. 39–52. https://doi.org/10.1007/978-3-319-63257-5_4.
Schuh, G., Anderl, R., Dumitrescu, R., Krüger, A. and Hompel, M. ten (2020), "Industrie 4.0 Maturity Index. Managing the Digital Transformation of Companies – UPDATE 2020 – (acatech STUDY)".
Steiber, A., Alänge, S., Ghosh, S. and Goncalves, D. (2021), "Digital transformation of industrial firms: an innovation diffusion perspective", European Journal of Innovation Management, Vol. 24 No. 3, pp. 799–819. https://doi.org/10.1108/EJIM-01-2020-0018.
Teichert, R. (2019), "Digital Transformation Maturity: A Systematic Review of Literature", Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, Vol. 67 No. 6, pp. 1673–1687. https://doi.org/10.11118/actaun201967061673.
Teo, T.S. and King, W.R. (1997), "Integration between Business Planning and Information Systems Planning: An Evolutionary-Contingency Perspective", Journal of Management Information Systems, Vol. 14 No. 1, pp. 185–214. https://doi.org/10.1080/07421222.1997.11518158.
Virkkala, P., Saarela, M., Hänninen, K., Kujala, J. and Simunaniemi, A.-M. (2020), "Business Maturity Models for Small and Medium-Sized Enterprises: A Systematic Literature Review", Management, pp. 137–155. https://doi.org/10.26493/1854-4231.15.137-155.
Wohlgemuth, V., Wenzel, M., Berger, E.S. and Eisend, M. (2019), "Dynamic capabilities and employee participation: The role of trust and informal control", European Management Journal, Vol. 37 No. 6, pp. 760–771. https://doi.org/10.1016/j.emj.2019.02.005.