Digitalization and operational data-driven decision-making
## A socio-technical investigation of the implications
for front-line production managers and workers

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Summary of Ph.D. dissertation

Digitalization is transforming manufacturing operations and jobs worldwide, as the increasing amount of real-time data made accessible to front-line employees is enabling the decentralization of data-driven decision-making (DDM). However, despite the great amount of literature about Industry 4.0, there is still a lack of empirical evidence on the effects that this has on operational performance. Also, the mechanisms through which the increasingly accessible real-time data can be exploited, i.e. the organizational and individual antecedents of operational DDM, still constitute a black-box that needs to be opened.

The objective of this dissertation is to explore the impact of digitalization, with a focus on the role of front-line managers and workers in making it effective. The theoretical approach consists of using organizational theories and knowledge management models to explain the reciprocal interplays among the socio-technical components of firms at the front-line level: digitalization *technologies*, decision-making *tasks/processes*, organizational *structure*, and *people*'s competencies. The empirical setting is the automotive sector, where the effects of Industry 4.0 are already visible, and analyzable, due to competition-driven pressure to adopt new technology and organizational practices. The research process relied on both quantitative and qualitative approaches, with methods ranging from logistic regressions and margins analyses to interview coding and quasi-experiment.
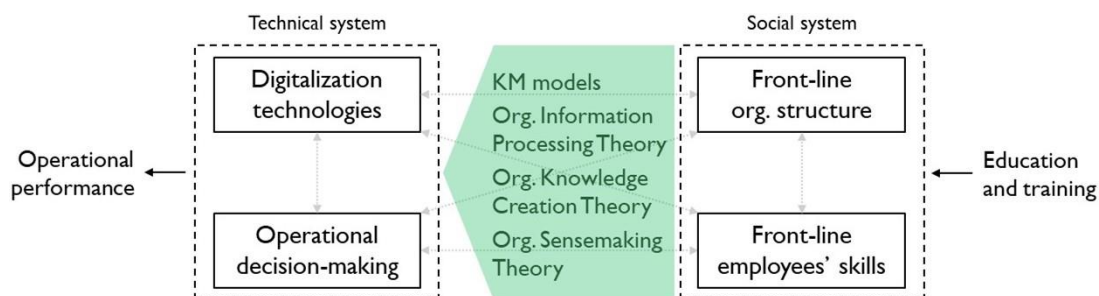
The results of the cross-country multi-respondent survey, issued to 138 automotive suppliers in Italy and the U.S., were two-fold. On the technical system side, DDM showed different interplays with different dimensions of digitalization in achieving cost reduction: data-driven firms benefit from increasing their levels of data integration, but their performance gets worse when the number of different

digitization technologies is higher. On the social system side, DDM is enabled by involved production workers and skilled team leaders (but not supervisors). A multiple-case study of 14 Italian and Spanish auto makers and suppliers allowed to confirm the centrality of team leaders in digitalizing firms, providing additional evidence for the delayering of supervisors and the deskilling of production workers. Last, a participatory action research conducted in the Italian education system allowed to test the effectiveness and key success factors of implementing challenge-based learning within a school-based apprenticeship program, with the aim of bridging the middle-skills gap induced by digitalization and transferring such practices to the automotive sector.

The results contribute to both theory and practice. The first contribution to theory is the empirical socio-technical framework proposed to study the digitalization of operations. Its building blocks are linked by triangulating organizational theories, knowledge management models, and empirical evidence. Digitalization is described as a skill-biased organizational and technical change, as individual competency gaps can hinder the diffusion of decentralized structures and DDM. Second, a new comprehensive socio-technical knowledge management model for a "data-information-knowledge-driven" operational decision-making is proposed, based on the disentanglement of data sensemaking, information processing, and knowledge creation, and of the tasks of the individuals involved in the process. Last, organizational and learning theories of knowledge creation are reconciled, with the proposal of a model – based on the concepts of the experiential learning theory and the organizational knowledge creation – aimed at anticipating the new Pi-shaped competency needs of the future middle-skill workers by complementing school-based on-the-job training with challenge-based off-the-job learning.

This dissertation also contributes to practice, with implications for managers and policymakers. First, managers are offered recommendations to exploit the benefits of digitalization: instil a decentralized and data-driven philosophy by vouching for lean manufacturing and training front-line employees, and make data integration effective through external collaborations with system integrators and internal cross-functional communication. Second, guidelines on the new central role of production team leaders are provided in terms of competency needs to undertake their managerial roles and the operational sensemaking, information processing, and knowledge creation that precede decision-making in operational environments teeming with real-time data. The last area of recommendations is directed toward policymakers but also firms, universities, and technical schools, i.e. the actors of the territory that are called to collaborate in order to anticipate middle-skill gaps by redesigning education.

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