Sustainable Internet-of-Things-based Manufacturing Systems: Industry 4.0 Wireless Networks, Advanced Digitalization, and Big Data-driven Smart Production.

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1. Introduction

Cutting-edge Industry 4.0 technologies enable companies to diminish the volume of resources misdirected and the emissions, bringing forth a prevailing low-carbon upside in addition to a decrease of the marginal production expense. (Liu and De Giovanni, 2019) The transformative capacity that functions within Industry 4.0, digitalization, and digital twins is instrumental in enhancing operational performance and cutting down process safety accidents. (Lee et al., 2019) Industry 4.0 can offer cost benefits of mass manufacturing with the adjustability of a small-batch producer. (Dachs et al., 2019)

2. Conceptual Framework and Literature Review

The socially impacted undertakings in Industry 4.0 entail collection investment and dimension of the customer market that regulates the product returns, shaping the competitive reverse logistics system. (Dev et al., 2020) Integrated high tech and networks supervise via sensors and coordinate via actuators the physical operations (Andrei et al., 2016; Mengoli et al., 2017; Nica, 2018a, b; Sandal and Krupka, 2018), commonly with input loops where physical operations and data processing shape each other. (Delicato et al., 2019) The production tools can make decisions in real time and clarify with the end user the alterations that can be implemented, in conformity with the assigned work streaming through the manufacturing system. (Rossit et al., 2019) Assimilating industrial automation systems leads to significant and groundbreaking characteristics via networking with team members (Ionescu, 2018; Nica, 2015; Popescu et al., 2017a, b; Valaskova et al., 2018), and assists in generating links between the cyber and physical realms. (Buchi et al., 2020) Repetitive and physically challenging tasks are handled by assistance systems, resulting in growing demands in respect of human resources' mental processes and performance. (Veile et al., 2019) Becoming competent at a distinct level is not instrumental as a mediator in the influence of Industry 4.0-based technologies on operational effectiveness. (Tortorella et al., 2020)

3. Methodology and Empirical Analysis

Using and replicating data from Capgemini, DAA, IoT Analytics GmbH, The Manufacturer, McKinsey, Oracle, PwC, US BLS, and WEF, I performed analyses and made estimates regarding smart factory transformation approach taken by players in different categories (%) and drivers of technological change and time to impact on employee skills (%). Data were analyzed using structural equation modeling.

4. Results and Discussion

With the swift advancement of Industry 4.0, cutting-edge technologies (e.g., big data, Internet of Things, and cloud computing) are progressively being applied, while established industrial production technologies will steadily develop or be replaced. (Lu et al., 2019) Industry 4.0 facilitates the monitoring of manufacturing operations by supplying instantaneous integration of flows and by furthering the fashioning of distinctive and custom-tailored commodities. (Moeuf et al., 2019) A digital production company is networked and interacts, assesses and harness data to more thoroughly handle smart operations back into the physical realm. (Hofmann et al., 2019) (Tables 1-7)

5. Conclusions and Implications

Table 1 Drivers of technological change and time to impact on employee skills (%)

Mobile Internet, cloud technology	82
Processing power, big data	76
New energy supplies and technologies	69
Internet of Things	62
Sharing economy, crowdsourcing	54
Robotics, autonomous transport	48
Artificial intelligence	36
Advanced manufacturing, 3D printing	22
Advanced materials, biotechnology	19

Sources: WEF; my survey among 4,200 individuals conducted June 2019.

Wireless technologies driven by the Internet of Things will remodel the industry as presently designed. (Garrido-Hidalgo et al., 2019) Human resource determinants are pivotal causal agents and constraints of Industry 4.0. (Horvath and Szabo, 2019) Organizations can harness Industry 4.0 technologies to catalyze economic, sustainable, and social value by fashioning the logistics role as a competitive mechanism, a social value producer, and a driving force for performance. (Tang and Veelenturf, 2019) The advancement of leandigitized manufacturing system constitutes a feasible business approach for corporate longevity in the Industry 4.0 environment. (Ghobakhloo and Fathi, 2019)

Note

The interviews were conducted online and data were weighted by five variables (age, race/ethnicity, gender, education, and geographic region) using the Census Bureau's American Community Survey to reflect reliably and accurately the demographic composition of the United States. The precision of the online polls was measured using a Bayesian credibility interval.

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Author Contributions

The author confirms being the sole contributor of this work and approved it for publication.

Conflict of Interest Statement

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Table 2 How important are the following data analytics skills and how well are they integrated in your company? (%)

	Important/Very important	All skills on board
Data science	94	26
Project management and implementation	91	69
Machine learning techniques and algorithms	86	37
Industrial process know-how	77	42
Cloud/Data storage	76	41
Computer engineering/ programming	74	38
IoT/M2M infrastructure	72	21
Business intelligence	67	46
Enterprise system integration	66	29

Sources: DAA; IoT Analytics GmbH; my survey among 4,200 individuals conducted June 2019.

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Table 5 Smart factory transformation approach taken by players in different categories (%)

	Digital Masters	Conservatives	Beginners
Business case and roadmap definition by consulting firms	88	67	46
Focused transformation such as operating model transformation, people transformation, and infrastructure transformation etc.	72	40	19
Partnership with tech providers for feasibility study	70	58	33
End-to-end technology solutions (e.g. Industrial IoT connecting all key manufacturing process etc.)	67	49	15
End-to-end transformation	58	52	34

Sources: Capgemini; my survey among 4,200 individuals conducted June 2019.

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Table 6 What area(s) do you plan on investing in Industry 4.0? (%)

Finance	6
R&D	48
Logistics	37
Production	76
Maintenance	42
Sales	28
IT	46
Don't know	2
Other (please specify)	3

Sources: The Manufacturer; Oracle; my survey among 4,200 individuals conducted June 2019.

Table 3 Which statement best describes your supply chain integration by digital maturity level? (%)

	Digital Novice	Digital Follower	Digital Innovator	Digital Champion

Isolated solutions and optimization of individual processes	34	36	25	5
Internal functions are integrated\and close collaboration	29	36	12	23
Digitally connected with external partners, integrated platforms for collaboration	2	10	59	29
Near-real-time end-to-end integration and planning platforms across external network	2	3	35	60

Sources: PwC; my survey among 4,200 individuals conducted June 2019.

Table 4 Which role do the following technologies play in your industrial data analysis? (%)

Spreadsheets	57
Advanced analytics platforms	52
Business intelligence tools	44
Predictive analytics tools	36
Simulation tools	35
Statistical package	34
Artificial intelligence	29
Event/Streaming analytics tools	27
Cognitive analytics	22
Edge/Fog Analytics	17

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Table 7 Net growth in work involving more application of expertise, interaction, and management (total work hours by activity type):

	Displaced hours	Added hours	Net change in hours
Applying expertise	569	2,293	1,724
Interacting with stakeholders	756	1,658	902
Managing and developing people	152	977	824
Unpredictable physical activities	1,054	1,198	144
Processing data	2,678	1,411	1,267
Collecting data	3,413	1,906	1,507
Predictable physical	3,097	1,521	1,576

Sources: ONET skill classification, US BLS; McKinsey Global Institute analysis; my 2019 data.

Abstract:
Empirical evidence on sustainable Internet-of-Things-based manufacturing systems has been scarcely documented in the literature. Using and replicating data from Capgemini, DAA, IoT Analytics GmbH, The Manufacturer, McKinsey, Oracle, PwC, US BLS, and WEF, I performed analyses and made estimates regarding smart factory transformation approach taken by players in different categories (%) and drivers of technological change and time to impact on employee skills (%). Data were analyzed using structural equation modeling.

JEL codes: E24; J21; J54; J64

Keywords: Internet of Things; manufacturing system; big data; smart production

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