BEYOND THE HYPE OF INDUSTRY 4.0: SEPARATING REALITIES FROM MYTHS

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Industry 4.0 in historical perspective: Defining the ‘field’

Industry 4.0 building blocks
- I. Technology trends of Industry 4.0
- II. Design principles of Industry 4.0
- III. Industry 4.0 archetype

Benefits of Industry 4.0
- I. Economic-productivity impacts
- II. Environmental sustainability impacts
- III. Social sustainability impacts
- IV. The negative impacts

Industry 4.0 Transformation
- I. The need for a strategic roadmap
- II. Best practices for digital transformation success
- III. Separating hype from reality
Industry 4.0 in historical perspective: Defining the ‘field’

- The first reference to Industry 4.0 occurred in 2011, yet, it is misleading to assume that Industry 4.0 is a sudden revolution utterly unaware of the industrial and technological revolutions that arose earlier. In reality, Industry 4.0 builds entirely upon the foundations of previous industrial revolutions. However, Industry 4.0 is expected to deliver the highest degree of digitalization, automation, virtualization, and decentralization across all industries, when coming to its maturity.

- The earlier studies tend to narrate Industry 4.0 as the digitalization of manufacturing processes, limiting it to factories, mainly in the form of implementing advanced digital manufacturing technologies such as 3D printing, modeling, simulation, virtualization, and data management technologies. More recent perspectives regard Industry 4.0 as the digital transformation of industrial value chains, a paradigm shift across various industries.

<table>
<thead>
<tr>
<th>1st Industrial revolution</th>
<th>2nd Industrial revolution</th>
<th>3rd Industrial revolution</th>
<th>4th Industrial revolution</th>
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<tbody>
<tr>
<td>End of 18th Century</td>
<td>Start of 20th Century</td>
<td>Early 1970s</td>
<td>Since 2011</td>
</tr>
<tr>
<td>- Steam power</td>
<td>- Assembly line</td>
<td>- Industrial electronics</td>
<td>- Internet of things</td>
</tr>
<tr>
<td>- Mechanization</td>
<td>- Electrical machinery</td>
<td>- Information technology</td>
<td>- Web of things</td>
</tr>
<tr>
<td></td>
<td>- Mass production</td>
<td>- Controllers</td>
<td>- Internet of people</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Industrial robotics</td>
<td>- Internet of services</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>- Cloud computing</td>
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<td></td>
<td></td>
<td>- Big data analytics</td>
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<td></td>
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<td></td>
<td>- Augmented reality</td>
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<td></td>
<td></td>
<td></td>
<td>- Virtualization</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>- Smart networks and sensors</td>
</tr>
<tr>
<td></td>
<td></td>
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<td>- Smart energy grids</td>
</tr>
</tbody>
</table>

| Environmental awareness and sustainability concerns | High |
| Process Reconfiguration Costs | Low |
| Product Customization and Individualization | High |
| Maintenance Simplicity | Low |
| Value creation | High |
| Energy consumption | High |
Nowadays, the scope of Industry 4.0 spans well beyond the manufacturing sector, involving related concepts such as Healthcare 4.0, Construction 4.0, Energy 4.0, and Transportation 4.0, among many others.
Industry 4.0 building blocks

To address the elusive nature of Industry 4.0 and the underlying digital transformation, the literature commonly characterizes Industry 4.0 based on its building blocks: a wide variety of underlying technology trends and design principles.

➢ Technology trends of Industry 4.0 are advanced digital, information, and operations technologies that are indispensable to shaping the undergoing digital industrial transformation.
➢ Design principles are desirable conditions that enable industrial entities to achieve digital transformation success and unlock the potential benefits of Industry 4.0 technology trends.

The framework of digital transformation success under Industry 4.0
Industry 4.0 could be categorized into two clusters, termed *core technologies* and *facilitating technologies*.

- The core technologies of industry 4.0 are the modern technological innovations that have been in development within the past few decades but have matured enough to become commercially available within the last decade.
- The facilitating technologies of Industry 4.0 are the more traditional, prevailing, and mature information and operations technologies that enable the core technologies of Industry 4.0 to deliver their intended functions.
Technology trends of Industry 4.0

(a) CPS-IIoT interaction

(b) Pillars of Internet of Everything

Machine and process controllers (PLS, SCADA, DCS, ...)
Monitoring and controlling manufacturing systems and data streams
Input and output signals (Actuators, smart sensors, machine vision, automated inspectors)

Signals
Component and equipment

Data
Shop floor

Information
Smart factory

Knowledge
Hyperconnected value chain

Informed decision making

Manufacturing execution system

Smart control level

Smart connection level

Industry 4.0 communication pyramid

CPS Networks Controller Cloud
Facilitating Technologies

Internet of people
Industrial internet of things
Internet of data
Internet of services

(a) CPS-IIoT interaction
(b) Pillars of Internet of Everything
Industry 4.0 archetype

Hyperconnected manufacturing management level
- Real-time production flow monitoring
- Real-time equipment management
- Time-in-system analysis
- Production scheduling
- Setup and configuration
- Deliveries optimization
- Reliability analysis
- Energy Audit
- Capital investments evaluation

Digital Supply Network Level

Smart stakeholders
- Effective communication
  - CSR strategy development
  - Relationship building
- Real-time inventory management and control across supply chain
  - Quantities
  - Spare parts
  - Logistics
  - Orders

Smart suppliers
- Digital collaboration
  - Quantities
  - Joint NPD
  - Capacities
  - Delivery dates

Smart logistics
- Smart (connected) customers
  - Future demand
  - Preferences
  - Quantities
  - Financial transaction

Smart products
- Customer integration

Smart Factory Level

Additive/Advanced manufacturing
- Individualised mass production
- Reduced time-to-market
- Manufacturing energy efficiency

Augmented and virtual reality
- Human error reduction
- Maintenance assistance
- Safety management
- Design and visualization
- On-the-job training

Automation and industrial robotics
- Shorter cycle times
- Reduced make mode
- Increased safety
- Improved quality
- Increased energy efficiency

Big data analytics
- Informed decision-making
- Customer behaviour prediction
- Shorter cycle times
- Reduced waste
- Increased safety
- Improved quality
- Improved production reliability

Blockchain
- Financial transaction security
- Assets history management
- Energy accounting

Cloud data and computing
- Disaster recovery
- Scalability
- Data accessibility

Cybersecurity
- Data Security
- Dependability improvement
- Real-time production monitoring
- AI-powered autonomous diagnostic
- Higher value creation
- Continuous energy consumption monitoring
- Higher value creation
- Anomaly proactiveness
- Continuous energy consumption monitoring
- Product-as-a-service business model
- Product lifetime optimization

Cyber-physical production systems
- Improved customer engagement
- Improved customer support
- Customer behaviour monitoring

Internet of services
- Internet of people
- Internet of things

Design Principals of Industry 4.0

- Vertical and horizontal integration
- Virtualization
- Interoperability
- Modularity
- Decentralization
- Product and service individualization
- Customer orientation
- Real-time capability

- Vertical and horizontal integration
- Virtualization
- Interoperability
- Modularity
- Decentralization
- Product and service individualization
- Customer orientation
- Real-time capability
### Industry 4.0 design principles

<table>
<thead>
<tr>
<th>Principle</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Real-time capability</td>
<td>93%</td>
</tr>
<tr>
<td>Horizontal Integration</td>
<td>86%</td>
</tr>
<tr>
<td>Vertical Integration</td>
<td>79%</td>
</tr>
<tr>
<td>Customer orientation</td>
<td>76%</td>
</tr>
<tr>
<td>Virtualization</td>
<td>74%</td>
</tr>
<tr>
<td>Interoperability</td>
<td>63%</td>
</tr>
<tr>
<td>Modularity</td>
<td>58%</td>
</tr>
<tr>
<td>Decentralization</td>
<td>51%</td>
</tr>
<tr>
<td>Service orientation</td>
<td>46%</td>
</tr>
<tr>
<td>Technical assistance</td>
<td>29%</td>
</tr>
</tbody>
</table>
There are different perspectives on the possible benefits of Industry 4.0 that drive the digital industrial revolution.

(a) Distribution of Industry 4.0 benefits
Economic-productivity impacts

(b) Industry 4.0 opportunities for manufacturing productivity

- Improved production monitoring and control
- Labor productivity
- Reduced inventory
- Reduced time to market
- Improved production planning
- Decreased maintenance costs
- Reduced machine downtime
- Reduced cost of quality

(c) Industry 4.0 opportunities for business competitiveness

- Organizational agility
- Supply chain integration
- Increased profitability
- Better innovation opportunity
- Internationalization opportunities
- Improved collaboration and knowledge sharing
- Improved market share
- Improved corporate image
Environmental and social sustainability impacts

(d) Social benefits of Industry 4.0

- Product individualization: 44
- Enhanced consumer experience and satisfaction: 36
- Improved working conditions of labor: 18
- New employment opportunities: 16
- Reduced cost of consumer goods: 14

(e) Environmental benefits of Industry 4.0

- Resource consumption efficiency: 36
- Waste reduction: 32
- Reduced harmful emissions: 28
- Energy consumption efficiency: 18
- Sustainable new products: 11

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The negative impacts of Industry 4.0

• Inventions often create more opportunities, and with that, jobs. Nevertheless, Industry 4.0 may very well lead to mass unemployment, at least in the short run.

• Industry 4.0, if governed and managed poorly, will lead to the polarization of the labor market. A skilled elite group of people who can use technology to be more productive tend to replace the labor of others and are paid accordingly, substantially resulting in income inequality.

• The digital transformation under Industry 4.0 is hugely resource and knowledge-intensive. Industry 4.0 leaders are usually the overpowering mega-corporations. The difference in Industry 4.0 transformation competency could increase the technological gap, hence inequality between corporations and even countries.

• More affordable, smarter, and personalized products, thanks to the advantages of Industry 4.0, mean shorter product lifecycle and overconsumption and rebound effect. A prolonged pattern of overconsumption and rebound effect, in turn, leads to environmental degradation and the eventual loss of resource bases.
Industry 4.0 Transformation

I. The need for a strategic roadmap

- External support for digitization
  - Industry 4.0 workshops
  - Manufacturing digitization consulting services
  - Professional consultation
  - Industry 4.0 digitization guidelines
  - Subsidized digitalization training
  - Subsidized strategic digitization management training
  - Digitalization readiness preassessment

- Management competency for digital transformation
  - Employee empowerment
  - Change readiness
  - Agile workplace culture
  - Change priority identification

- Business partner digital maturity
  - Change-related cost/risk/benefit assessment
  - Digital culture (e.g., digital leadership, digital attitude, IDT competency, and digital thinking) assessment
  - IDT resource availability
  - IDT investment prioritization
  - External IDT support prioritization
  - IDT technical assistance
  - IDT integrability
  - Subsidized IDT training for employees
  - SME-friendly regulation for IDT service providers
  - Collaborative digitization planning
  - Integrated capability-building ecosystem

- Information and digital technology expertise
  - IDT resource availability
  - IDT investment prioritization
  - IDT technical assistance
  - IDT integrability
  - Support and commitment
  - Resource allocation
  - Strategy development

- Manufacturing digitalization strategic roadmapping
  - Identifying digital talent gaps
  - Measuring digital competences
  - IDT/OT shortcoming assessment

- Change Management Competency
  - Agile workplace culture
  - Change priority identification
  - Digitalization project management
  - IDT leveraging competency
  - IDT vendor selection
  - ITD integration knowledge

- Cybersecurity maturity
  - Cybersecurity technical assistance
  - Cybersecurity skill development
  - Cybersecurity policy enforcement
  - Cybersecurity emergency planning

- Information and digital technology readiness
  - Methodical OT readiness assessment
  - OT maturity prioritization

- Operations technology readiness
  - Crossing the gap
  - Supplying necessary technology
  - Cybersecurity risk assessments
  - Cybersecurity technical assistance
  - Cybersecurity policy enforcement
  - Cybersecurity emergency planning

- Digitalization readiness preassessment
  - Funding employee training
  - Recruiting top talent
  - Timely resource allocation
  - Funding the necessary planning and analytics tools
  - Funding legacy hardware upgrade

- Resource availability
  - Financial aids
  - Subsidized digitization training and consultancy
  - Digitalization roadmap development guidelines
  - Professional consultation

- Change priority identification
  - Change-related cost/risk/benefit assessment
  - Digital culture (e.g., digital leadership, digital attitude, IDT competency, and digital thinking) assessment

- Cybersecurity technical assistance
  - Cybersecurity technical assistance
  - Cybersecurity skill development
  - Cybersecurity policy enforcement
  - Cybersecurity emergency planning

- IDT resource alignment
  - ITD skill development strategies
  - Risk management proactiveness
  - Digitization contingency strategies
  - Improved inter-team communication

- Change management proactiveness
  - Digitization Management process simplification
  - Digitization Management process simplification
  - Improved inter-team communication

- Effective communication
  - Progress measurement and performance analysis
  - Informed decision-making
  - Change resistance management
  - Agile workplace culture

- Secure communications
  - Information sharing security
  - Cybersecurity measure effectiveness
  - Cybersecurity awareness
  - IDT resilience

- Operations technology readiness
  - Increased interoperability of OTs
  - Enhanced integrability of OTs
  - Methodical OT readiness assessment
  - OT maturity prioritization

- Improved inter-team communication
  - Secure communications
  - Information sharing security
  - Cybersecurity measure effectiveness
  - Cybersecurity awareness
  - IDT resilience

- Enhanced inter-team communication
  - Secure communications
  - Information sharing security
  - Cybersecurity measure effectiveness
  - Cybersecurity awareness
  - IDT resilience

- System integration
  - Cross-functional team collaboration
  - Interoperability assessment
  - System integration knowledge

- Methodical OT readiness assessment
  - OT maturity prioritization
  - Cybersecurity technical assistance
  - Cybersecurity policy enforcement
  - Cybersecurity emergency planning

- IDT resource alignment
  - ITD skill development strategies
  - Risk management proactiveness
  - Digitization contingency strategies
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<td><strong>Operations technology maturity</strong></td>
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<td><strong>External support for digitalization</strong></td>
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<td><strong>Human resource readiness for digitalization</strong></td>
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<td><strong>Management support and commitment</strong></td>
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<td><strong>Change management competency</strong></td>
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<td><strong>Dynamic organizational culture</strong></td>
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<td><strong>Data security, ownership, and protection regulation</strong></td>
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<td><strong>Digitalization strategic planning capability</strong></td>
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<td><strong>Digitalization preassessment capability</strong></td>
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- **Mentions as barrier**
- **Mentions as enabler**
- **Total mentions**

![Bar chart showing mentions as barrier, mentions as enabler, and total mentions]
Industry 4.0 Transformation

I. Separating hype from reality

• Industry 4.0 technologies are being adopted across the Industry. The adoption rate is increasing, but the overall rate is still very low. There is a massive discrepancy in the level of Industry 4.0 digital transformation across various industries, businesses of various sizes, and countries.

• The scope of Industry 4.0 spans beyond focal firms. Industry 4.0 is also transformative, as it completely changes the rules of business. However, the digitalization journey under Industry 4.0 can be started in the form of smaller digitalization projects at the corporate or value chain levels. When it comes to Industry 4.0, businesses need to have a clear picture of the digital transformation and its underlying requirements, current risks, and opportunities. Businesses also need to understand what their peers and competitors are currently doing and plan to do in the future to drive value and capture competitive advantage under the digitalization scenario.

• Many of the manufacturing-productivity benefits of Industry 4.0 is empirically proven. Nonetheless, the majority of the socio-environmental implications of Industry 4.0 are theoretical speculations.

• The majority of Industry 4.0 technologies have been available for industrial use during the past few decades. However, they have become more mature and commercially viable during the last few years. Digital transformation is not merely about purchasing and implementing these technologies. Without developing and materializing the core design principles of Industry 4.0, these technologies cannot deliver the intended benefits.
Thank You

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