

# **Industrialisation, Ecologicalisation and Digitalisation (IED): Building a theoretical framework for sustainable development**

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## **Purpose:**

In the past two decades, manufacturing has witnessed significant transformations along with challenges (Moore, 1993). The worldwide established contexts, experiences, and principal models of industrial systems are no longer practical, instead it starts to lean towards the integration of industrialisation and ecological concerns (Shi et al., 2021; Campbell-Johnston et al., 2020). Meanwhile, digital transformation has enabled flexible & adaptable new organisational structures (Jian et al., 2017). The Covid-19 pandemic has further revealed the importance of resilience in the current volatility, uncertainty, complexity, and ambiguity (VUCA) conditions(Li, 2020), which requires for a holistic evolution process considering the synergy between industrialisation, ecologicalisation and digitalisation (IED). This paper aims to answer the research question: “How to integrate the three aims – industrialisation, ecologicalisation and digitalisation – for sustainable development?”

## **Design/methodology/approach:**

A systematic literature review is conducted, and an integrated framework is proposed based on the review of these 5 areas as well as cases.

## **Findings:**

After a thorough exploration into the five interactive bodies of knowledge within IED:“Industrialisation-Ecologicalisation”,“Ecologicalisation-Digitalisation”,“Industrialisation-Digitalisation”,“Digitalisation-Industrialisation”, and“Digitalisation-New Organisation Structure” is covered. Key themes are summarised with the identification of research gaps. A theoretical framework is then synthesised and developed aiming to achieve synergy from IED with the modules, integration architecture, mechanism, and dynamic paths. To articulate the key research question, we propose the following theoretical framework (Figure 1), with the aim to achieve the integration and synergy of IED. Based on the framework, a new process orientated abductive research method is proposed with respect to the research (Table 1).

## **Practical implications:**

Organisations can use the framework to rethink & redesign their business model, combine business growth & sustainability in a proactive way, and add value in the long-term. In a

boarder context, policy makers can also refer to our framework to support circular economy and digitalisation with value capture and creation. NGOs can also use the findings to support the ecologicalisation of industrial systems across different regions.

### **Relevance/contribution:**

First, we have critically reviewed and interpreted the current literature of IED in terms of 5 groups, key themes and research gaps in these 5 groups are identified, which can capture the emerging trends of those theories with critical interpretation. We then have proposed a theory framework (Figure 1) combining IED which is a cross-discipline one serving as a foundation for future research. Third, we have designed a process orientated abductive methodology to validate the framework. The core modules and interaction mechanism are pointed out, which scholars from various backgrounds can develop relevant research. Thus, our findings can be a platform to promote international research, inviting scholars to develop and find deliverables to enrich the theory together.

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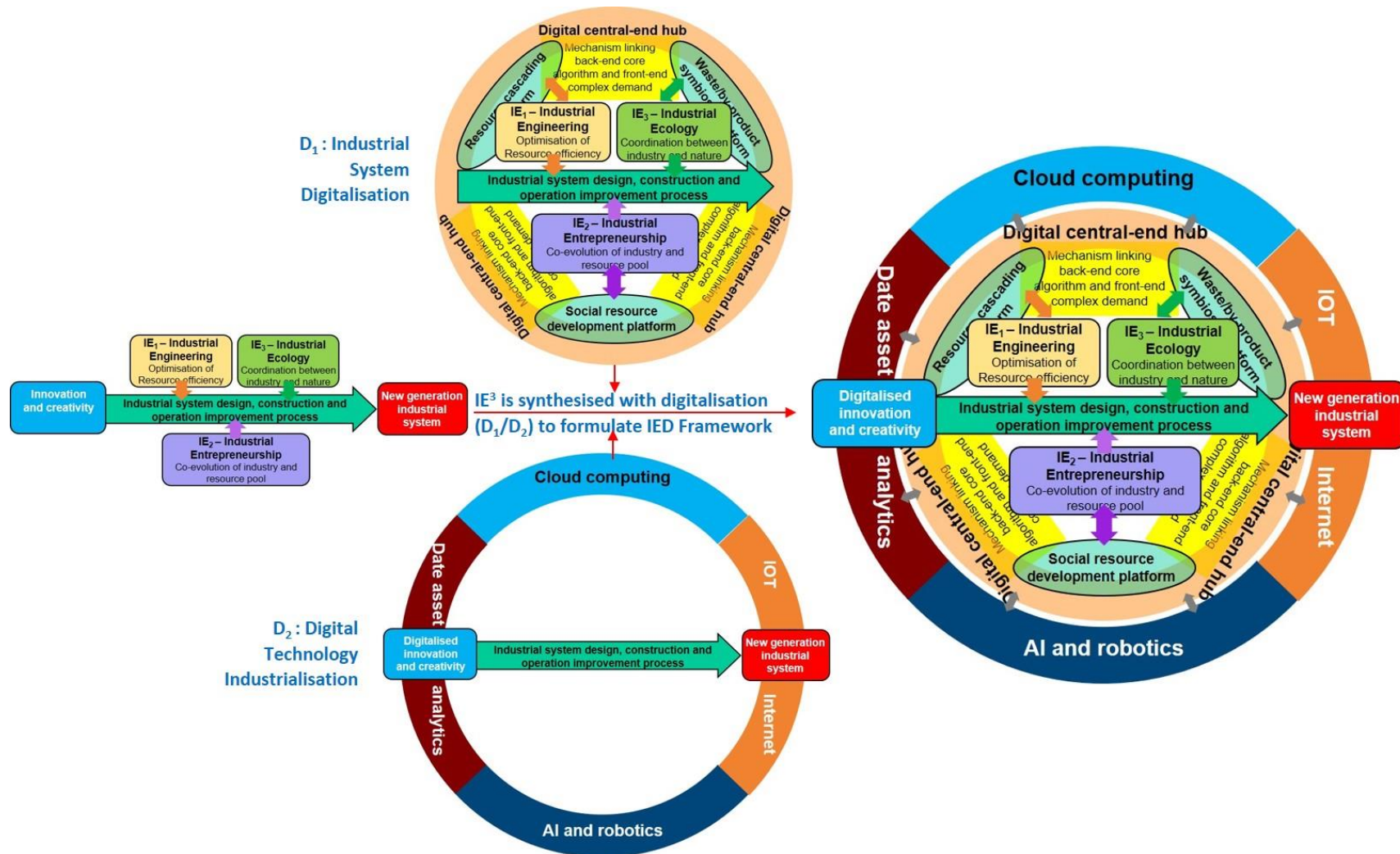


Figure 1 A theoretical framework to integrate IED

Table 1. IED research modules and relevant research approaches

Research Design Research Module		Research Module Objectives	Main Research Module Tasks	Key Research Approaches	Main Research Process/Stages
<b>IE<sub>1</sub> Module – Industrial Eng.</b>		Value-based Resource Efficiency	<ul style="list-style-type: none"> <li>Resource cascading</li> <li>nRs (Re-...)</li> </ul>	Case observation to capture the best practices and prescription	<ul style="list-style-type: none"> <li>Industry &amp; literature review for selecting cases</li> <li>Data collection/ analysis of current practices</li> </ul>
<b>IE<sub>2</sub> Module – Innovative Entrepreneurship</b>		Design-construct industrial system from R Pool	<ul style="list-style-type: none"> <li>Innovation</li> <li>Business models</li> </ul>	Interviews with current leaders within industry to identify current business models and innovation efforts	Data collection/ analysis of existing systems and reflecting upon it
<b>IE<sub>3</sub> Module – Industrial Symbiosis for New Value Creation</b>		Waste and by-product utilisation through industrialisation	<ul style="list-style-type: none"> <li>Resource efficiency</li> <li>Supply chain/ network</li> </ul>	Case observation to understand processes and implementation	<ul style="list-style-type: none"> <li>Industry &amp; literature review for selecting cases</li> <li>Data collection/ analysis of recent methods</li> </ul>
<b>D<sub>1</sub> Module – Industrial System Digitalisation</b>		Upgrading existing industrial system through digitalisation	<ul style="list-style-type: none"> <li>Lifecycle analysis &amp; assessments</li> <li>Smart manufacturing</li> </ul>	<ul style="list-style-type: none"> <li>Interviews with existing experts on the topic</li> <li>Experimentation of theoretical ideas in this new field</li> </ul>	<ul style="list-style-type: none"> <li>Hypothesising the implementation of the system and its impacts</li> <li>Data collection on its practical implications</li> </ul>
<b>D<sub>2</sub> Module – Digital Technology Industrialisation</b>		Identification of some digital technologies and transformation of them towards new industries	Cloud based programming Platforms for increased flexibility & adaptability	Surveys to obtain data on the many different types of cloud computing & platforms in relation to industry	Data collection on the different digital tools and their individual/ collection impact on industry
Synthesising Modules	<b>Resource cascading platform</b>	Digital platform dedicated to the IE <sub>1</sub> Module in order to provide relevant data and tool bases	<ul style="list-style-type: none"> <li>Allocation of resources in the ecosystem</li> <li>Optimising use of all materials (raw &amp; waste)</li> </ul>	Interviews with individuals with know-how on database/ platform creation	Data analysis of the process and difficulties in creating a resource cascading system
	<b>Social resource development platform</b>	Digital platform dedicated to the IE <sub>2</sub> Module in order to provide relevant data and tool bases	<ul style="list-style-type: none"> <li>Nurturing business ecosystems</li> <li>System stability</li> </ul>	Interviews with industry leaders/ municipalities/ government	Data collection on how to best create a stable & nurturing environment for the industry
	<b>Waste/by-product symbiosis platform</b>	Digital platform dedicated to the IE <sub>3</sub> Module in order to provide relevant data and tool bases	<ul style="list-style-type: none"> <li>Identification of links via waste/ by-products</li> <li>Managing complex supply chain/networks</li> </ul>	<ul style="list-style-type: none"> <li>Surveys to obtain information on what types of waste/by-products exist</li> <li>Focus groups with companies in the industry</li> </ul>	Data collection/analysis on the types of waste/by-products and their potential links
	<b>Digital central-end hub</b>	Bridging platforms and specialised digital technology	Increasing the integration & efficiency of the different parts of the industry	Experimentation in creating a working database for IE modules	Preliminary construction of an initial database
	<b>Open module for the emerging requirements</b>	Digital platform for emerging issue and requirement in order to provide relevant data and tool base supports	Open innovation Investigation into the potential of new digital platforms	Surveys to capture data regarding emerging issues and new breakthroughs in technology	Identification of new ideas and requirements for the research/ framework