Maissa Ftiti

# Governing Digital Renewal in Mature Industrial Clusters

The DICAAAP Framework and the Energy Vaasa Case

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**Author:** Maissa Ftiti
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**ABSTRACT:**

Industrial clusters have traditionally been understood as place-based systems whose competitiveness relies on geographic proximity, dense inter-firm networks, and strong institutional embeddedness. However, digital transformation and increasing global connectivity challenge these assumptions, particularly for mature clusters facing risks of stagnation, lock-in, and declining adaptability. While recent literature has introduced the concept of the Digital Industrial Cluster (DIC) to describe digitally mediated forms of agglomeration, empirical understanding remains limited regarding how established industrial clusters operationalise digital transformation as a strategic mechanism for renewal and cross-regional scaling.

This thesis addresses this gap by developing and empirically examining the Digital Industrial Cluster Activation, Acceleration, and Adaptation Pathway (DICAAAP), a staged and governance-oriented framework explaining how mature industrial clusters transition toward functioning Digital Industrial Clusters. Integrating cluster life cycle theory, evolutionary economic geography, digital transformation research, and platform governance perspectives, the DICAAAP framework conceptualises digital transformation not as a purely technological upgrade but as a coordination and governance challenge embedded within institutional and life cycle dynamics.

The study adopts a qualitative, abductive research design and applies the framework to an in-depth single-case study of the Energy Vaasa cluster in Finland. Empirical material was collected through twelve semi-structured interviews with cluster management actors, industrial firms, regional policymakers, and external cluster and policy experts, complemented by relevant secondary sources. The DICAAAP stages functioned as sensitising concepts guiding analysis rather than predetermined categories.

The findings indicate that Energy Vaasa benefits from strong institutional embeddedness and trust-based collaboration, yet lacks shared life-cycle diagnostics, collectively embedded digital coordination infrastructure, and institutionalised governance arrangements supporting cluster-level digital transformation. The analysis positions the cluster between incomplete Activation and limited Acceleration, demonstrating that digital cluster renewal depends less on technological availability than on coordination capacity, staged orchestration, and institutionalisation.

**KEYWORDS:** Strategic Cluster Renewal, Digital industrial cluster, Cluster life cycle, Digital transformation, DICAAAP framework, Energy Vaasa Cluster

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## Abbreviations

AI – Artificial Intelligence

DT – Digital Transformation

DIC – Digital Industrial Cluster

CLC – Cluster Life Cycle

NEG – New Economic Geography

EEG – Evolutionary Economic Geography

DICAAAP – Digital Industrial Cluster Activation Acceleration and Adaptation Pathway

# 1 Introduction

The concept of industrial agglomeration has long been central to regional economic thought. Early foundations were laid by Alfred Marshall (1920), who demonstrated how geographic concentration fosters innovation, efficiency, and specialization. Walter Isard (1956) later integrated location theory, economics, and geography into the emerging field of regional science. Over time, this interdisciplinary tradition evolved into influential concepts such as new economic geography, innovation systems, and spatial development theory (Duranton, 2011; Ortega-Colomer et al., 2016; Storper, 2009). Among these, Michael Porter's cluster model (1990, 1998, 2000) became particularly influential, highlighting collective efficiency, knowledge spillovers, and territorial competitiveness (Maskell, 2001; Schmitz, 1995). Despite their contributions, these approaches remain fundamentally anchored in the logic of geographic proximity.

The transformative dynamics of digital technologies and globalization have challenged these spatial assumptions (Leamer & Storper, 2001; Müller et al., 2018). Collaboration, innovation, and knowledge exchange are no longer strictly bound to physical location, prompting a re-evaluation of how clusters evolve and compete in digitally connected environments (Fernandez-Escobedo et al., 2024). Digital transformation (DT), further accelerated by the COVID-19 pandemic, has pushed firms toward new modes of operation supported by ICT and Industry 4.0 technologies (Alcácer et al., 2016; Guo et al., 2020; Knell, 2021). While DT disrupts location-based advantages, regional assets such as knowledge spillovers and entrepreneurship remain critical in today's knowledge economy (Bathelt & Li, 2014; Jofre-Monseny et al., 2014).

For industrial clusters, digital transformation presents both challenges and opportunities under conditions of globalization and rapid technological change (Porter & Heppelmann, 2015; UNCTAD, 2021). Industry 4.0 has further accelerated this shift, forcing firms and clusters to adapt to increasingly digital environments (Frank et al., 2019; Lasi et al., 2014; Rüßmann et al., 2015). Consequently, there is a growing demand for conceptual models

that integrate technological change with spatial, institutional, and organizational dynamics (Almeida et al., 2020; Fernandez-Escobedo et al., 2024; Malmberg & Maskell, 2002).

In response, recent scholarship has proposed a range of digital agglomeration models that explore how digital spaces can complement or partially substitute traditional forms of geographic clustering. Fernandez-Escobedo et al. (2023) identify four prominent approaches: the Virtual Industry Cluster (VIC), the Digital Business Ecosystem (DBE), the e-Sourcing Cluster (eSoC), and the Digital Industrial Cluster (DIC). While the VIC, DBE, and eSoC emphasise global digital connectivity, they encounter limitations in reconciling digital flexibility with the continued relevance of physical proximity and localized coordination (Babkin et al., 2017, 2018; Fernandez-Escobedo & Cuevas-Vargas, 2023).

The Digital Industrial Cluster (DIC) emerges as a particularly promising model in this context. It is conceptualized as a virtual space and online hub designed to organize and govern digital interactions among organizations embedded in interrelated, yet geographically dispersed, industrial clusters. By combining digital connectivity with localized industrial foundations, the DIC seeks to bridge the divide between spatially grounded clustering and digitally mediated coordination (Babkin et al., 2018; Bathelt & Li, 2014; Delgado et al., 2014). However, the DIC remains largely conceptual, and its practical implementation in mature cluster contexts is still poorly understood.

## 1.1 Research gap

As industrial clusters mature, they often face structural rigidities, lock-in effects, or declining innovation capacity, which may lead to stagnation or gradual decline (Hassink, 2010; Menzel & Fornahl, 2010; Mossig & Schieber, 2016). Cluster life cycle theory explicitly recognises these trajectories and highlights the need for continuous reassessment to sustain competitiveness over time (König & Brenner, 2025; Ostapenko et al., 2022, 2025). However, traditional cluster models provide limited guidance on how mature clusters can strategically transform in response to major technological, market, or institutional shifts, particularly in relation to digital transformation (Hira, 2019).

Meanwhile, the Digital Industrial Cluster (DIC) model has emerged as a theoretical response to the growing detachment of innovation from strict geographic proximity (Fernandez-Escobedo et al., 2024). As Fernandez-Escobedo et al. (2024) explicitly state:

> "*This article proposes a novel policy tool that finds its foundations not only in traditional industrial clusters but also in the digitalization and virtualization phenomenon, making a theoretical contribution that expects to find its way through the future world shaped by Industry 4.0. This policy tool seizes the benefits of geographical proximity and uses technology to leverage the positive externalities of interrelatedness, with a multiregional approach*." (p. 544)

By enabling digitally mediated collaboration among geographically dispersed yet industrially related actors, the DIC proposes a platform-based structure for knowledge exchange, innovation, and cross-regional coordination. However, the original authors also acknowledge important conceptual and empirical limitations of the model. Fernandez-Escobedo and Cuevas-Vargas (2023) note that:

> "*Further empirical research is necessary to assess the potential benefits of DIC deployment and identify regions capable to participate in such a project. Collecting and analysing data related to the penetration of ICT and Industry 4.0 in regions with prevalent traditional industrial clusters would facilitate the efforts of researchers and policymakers in overcoming the current challenges faced by the DIC deployment model*." (p. 1137)

This acknowledged limitation highlights the urgent need for empirical investigation and for operational frameworks capable of translating the DIC concept into practice. More broadly, it exposes a critical research gap at the intersection of digital agglomeration theory and cluster life cycle thinking. Existing studies rarely examine how digital infrastructure and platform-based collaboration can be systematically mobilised as

mechanisms for mature cluster renewal and life cycle extension. As a result, it remains unclear how the DIC model can be operationalised as a strategic tool to revitalise mature clusters, enable digital transformation, and support new trajectories of growth and cross-regional expansion.

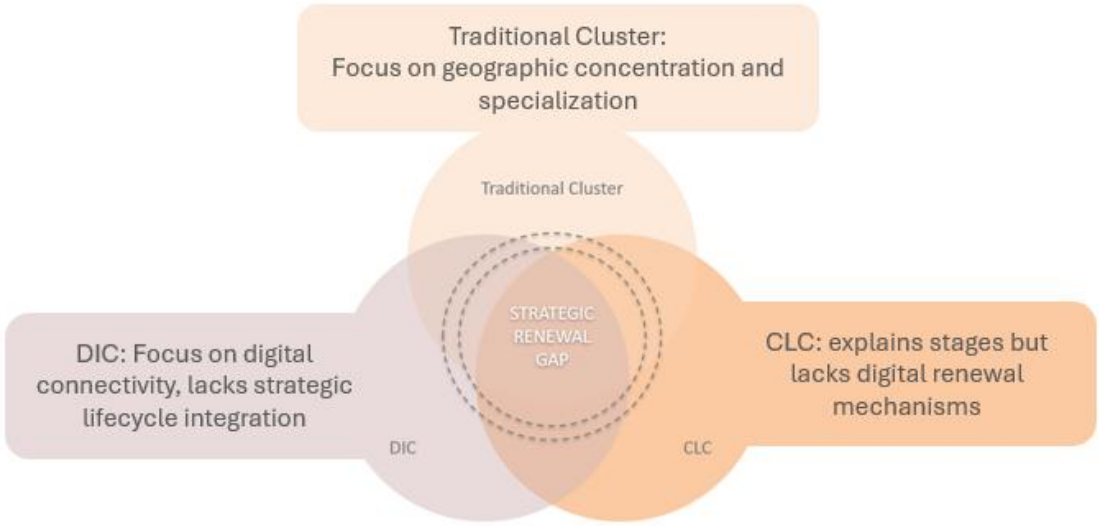


**Figure 1. Conceptual illustration of the strategic renewal gap between traditional cluster theory, Digital Industrial Clusters, and Cluster Life Cycle approaches (Author´s own illustration).**

In this thesis, the DIC represents the target configuration, while DICAAAP specifies the staged governance process through which a mature cluster can move toward that configuration. To address this gap, the thesis develops the Digital Industrial Cluster Activation, Acceleration, and Adaptation Pathway (DICAAAP), a staged governance framework designed to activate, accelerate, and institutionalise digital transformation in mature industrial clusters.

While the Digital Industrial Cluster (DIC) provides the conceptual architecture, DICAAAP translates this architecture into an actionable pathway by integrating platform-based collaboration, dynamic capabilities, and ecosystem orchestration. In doing so, the study contributes a generalisable framework that explains how digital cluster renewal can be governed in practice. Given the exploratory nature of this gap, the framework is refined

abductively through iterative engagement with empirical material from a mature industrial cluster context.

## 1.2 Research aims and research question

The aim of this research is to develop and empirically examine a strategic framework that operationalises the Digital Industrial Cluster (DIC) model as a mechanism for the renewal and cross-regional scaling of mature industrial clusters. In doing so, the study seeks to translate the DIC model from a primarily conceptual construct into an analytically usable and strategically grounded framework capable of guiding digital transformation in established cluster ecosystems.

To fulfil this aim, the research investigates how digitally mediated coordination, platform-based collaboration, and governance arrangements can be structured to support cluster-level digital transformation. An in-depth empirical case is employed to examine how abstract digital agglomeration concepts can be translated into analytically robust and practically relevant processes within a mature industrial cluster context. While the framework aspires to broader relevance, its empirical validation is necessarily concentrated on a single mature cluster, which sets important but transparent boundaries for generalisation.

The main research question guiding this thesis is:
**How can the Digital Industrial Cluster (DIC) model be operationalised as a strategic tool to enable the renewal and cross-regional scaling of mature industrial clusters?**

This thesis addresses the research question by developing the DICAAAP framework as a staged, governance-oriented pathway through which the Digital Industrial Cluster model can be operationalised. In this thesis, operationalisation refers to specifying a staged process of diagnosis, orchestration, scaling, and institutionalisation through which digitally mediated coordination supports cluster renewal and cross-regional expansion.

## 1.3 Empirical context: Energy Vaasa

This study is empirically grounded in the Energy Vaasa cluster, the largest Nordic energy technology ecosystem coordinated by Technology Centre Merinova. The cluster comprises over 180 firms, universities, research organisations, and public actors, and is internationally oriented toward energy technology, decarbonisation, and export-driven innovation. Energy Vaasa represents a mature industrial cluster with a long history of inter-firm collaboration, institutional embeddedness, and policy support.

The cluster provides a relevant empirical context for this research due to its long history and exposure to increasing pressures related to digitalisation and cross-regional collaboration. These characteristics position Energy Vaasa at the intersection of cluster life cycle dynamics and digital transformation challenges, making it a suitable setting for examining how the Digital Industrial Cluster (DIC) model can be operationalised in practice. Merinova's role as a neutral meta-organiser of the cluster further offers a clear governance focal point through which emerging digital orchestration processes can be traced and analysed.

The empirical analysis of Energy Vaasa serves as the basis for exploring digitally mediated coordination and governance arrangements within an established cluster ecosystem. Further details regarding case selection, data collection, and methodological considerations are provided in Chapter 4.

## 1.4 Thesis structure

To address the research aim and guiding research question, this thesis is organised into seven chapters. Chapter 1 introduces the research background, identifies the research gap, and formulates the research aim and central research question. Chapter 2 reviews the literature, tracing the evolution of cluster theory toward digitally enabled forms and positioning the Digital Industrial Cluster (DIC) model within cluster life cycle, digital transformation, and digital agglomeration research. Chapter 3 develops the conceptual

framework by introducing the DICAAAP (Digital Industrial Cluster Activation, Acceleration, and Adaptation Pathway) as a governance-oriented mechanism for operationalising the DIC model. Chapter 4 outlines the research methodology, including the philosophical stance, qualitative single-case study design, and analytical approach. Chapter 5 presents the empirical findings based on interviews with key stakeholders in the Energy Vaasa ecosystem. Chapter 6 analyses these findings in relation to the theoretical framework and develops the revised DICAAAP interpretation. Chapter 7 discusses the findings in relation to existing literature, outlines the study's theoretical contributions, and presents managerial and policy implications, limitations, and directions for future research. Table 1 summarises the alignment between the research aim, research question, and thesis structure.

**Table 1: Alignment between research aim, research question, analytical focus, and chapter structure**

| Research Component | Focus | Linked Chapter(s) | Output / Contribution |
|---|---|---|---|
| **Research Aim** | To operationalise the Digital Industrial Cluster (DIC) model as a strategic tool for the renewal and cross-regional scaling of mature industrial clusters | Chapter 1 (Introduction) | Defines the purpose, relevance, and scope of the study |
| **Main Research Question** | How can the Digital Industrial Cluster (DIC) model be operationalised as a strategic tool to enable the renewal and cross-regional scaling of mature industrial clusters? | Chapters 2–6 | Provides a unifying analytical lens guiding theory development, empirical analysis, and framework construction |
| **Theoretical Analysis** | Integration of cluster life cycle theory, digital transformation, and digital agglomeration perspectives | Chapter 2 (Literature Review), Chapter 3 (Conceptual Framework) | Establishes the theoretical foundation and identifies mechanisms of renewal, stagnation, and digital coordination |
| **Empirical Investigation (Energy Vaasa)** | Examination of how digital coordination, collaboration, and governance challenges unfold in a mature industrial cluster | Chapter 4 (Methodology), Chapter 5 (Findings), Chapter 6 (Analysis) | Generates empirically grounded insights into cluster maturity, renewal pressures, and coordination gaps |
| **Framework Development (DICAAAP)** | Development and analytical application of a staged pathway for operationalising the DIC model in practice | Chapter 3 (Framework), Chapter 6 (Analysis), Chapter 7 (Discussion and Contributions) | Produces the DICAAAP framework as a governance-oriented, actionable pathway for digital cluster renewal |
| **Conclusion** | Synthesis of theoretical insights, empirical findings, and framework implications | Chapter 7 (Conclusion and Recommendations) | Summarises key findings, discusses theoretical and practical implications, and identifies limitations and directions for future research. |

# 2 Literature review

The concept of geography has played a foundational role in the study of industrial clusters. From Alfred Marshall's industrial districts to contemporary digital ecosystems, the spatial dimension has consistently shaped understandings of innovation, competitiveness, and regional economic development. However, in today's globally connected and digitally mediated world, the traditional view of geography as fixed, physical proximity appears increasingly simplistic.

This chapter traces the historical evolution of cluster theory through the lens of geography, asking not only how space has influenced economic activity, but how understandings of geography itself have been fundamentally reshaped. By moving from classical notions of location and distance to relational, institutional, and digital interpretations, the chapter aims to reconceptualise geography as a dynamic, hybrid construct, no longer confined to physical space but deeply embedded in networks, institutions, and flows of knowledge.

## 2.1 Historical foundations of cluster theory

The intellectual foundations of cluster theory are most clearly rooted in Alfred Marshall's Principles of Economics (1920), where he introduced the concept of industrial districts as localised concentrations of firms that benefit from shared labour pools, supplier networks, and informal knowledge spillovers. In this early understanding, geography is interpreted largely in physical terms: proximity facilitates face-to-face interaction, reduces transaction costs, and enhances the diffusion of tacit knowledge (Asheim et al., 2007; Marshall, 1920). This view laid the groundwork for what later became known as agglomeration economies, establishing a strong link between spatial proximity and economic advantage (Audretsch & Feldman, 1996).

By the mid-20th century, the spatial dimension of economic activity was increasingly formalised through the development of analytical location theories. As synthesised by

Fujita, Krugman, and Venables (1999), the foundational contributions of Johann Heinrich von Thünen (1826), Wilhelm Launhardt (1885), and Alfred Weber (1929) laid the groundwork for spatial economics and industrial location theory, advancing models that aimed to find the optimal firm locations based on transport costs, land rents, and market access (Fujita et al., 1999). This rationalist tradition led to the development of regional science, most notably through the work of Walter Isard (1956, 1960), who integrated classical location theory with input–output modelling and quantitative spatial analysis. While these approaches marked a methodological breakthrough, they conceptualised space primarily in geometric and physical terms, as a neutral, uniform, flat environment governed by distance and efficiency. Over time, critical perspectives emerged, questioning this geometric view of space, emphasising instead the socio-institutional and relational complexities of geographic space (Scott, 2000).

A significant conceptual shift occurred in the 1970s and 1980s, driven by what became known as the cultural turn in economic geography. This period saw growing recognition that economic space is not merely objective and static, but socially and institutionally constructed (Massey, 1994; Scott, 1988). Influential schools of thought emerged during this time, notably the Italian industrial districts (Becattini, 1990; Brusco, 1982), the GREMI network on innovative environments (Aydalot & Keeble, 1988; Camagni, 1995), and the Californian school (Scott & Storper, 1987; Storper, 1997). These approaches emphasise that trust, local culture, and institutional coordination are central to regional innovation. Consequently, geography was reconceptualised in relational terms, where proximity referred not only to spatial closeness but also to shared norms, networks, and learning processes (Amin & Thrift, 1992; Martin & Sunley, 2003; Maskell & Malmberg, 1999).

The 1990s brought further challenges to traditional geographic thinking with the intensification of globalisation. Clusters were no longer understood as locally bounded systems but increasingly seen as nodes embedded within global production networks. Theories of multinational enterprises (Rugman & Verbeke, 2001), global value chains

(Gereffi, 1999), and knowledge pipelines (Bathelt et al., 2004) revealed how regions could combine local embeddedness with global connectivity. In this phase, geography became dual in nature, simultaneously local and trans-local, embedded in both place and network position (Coe et al., 2008).

In the 21st century, digital transformation has introduced a new layer of complexity into the geography of clusters. The emergence of virtual teams, online collaboration, and platform-based innovation challenges the primacy of physical proximity (Malecki, 2010). However, empirical research suggests that digital clusters still rely on localised ecosystems, including access to skilled labour, research institutions, venture capital, and supportive policies (Carayannis & Von Zedtwitz, 2005; Feldman, 2014; Götz & Jankowska, 2017; McCann & Ortega-Argilés, 2015). Thus, geography today is best understood as a hybrid construct, that synthesises physical infrastructure, institutional depth, social relationships, and digital connectivity (Boschma, 2005; Kuk & Janssen, 2013).

In summary, the evolution of cluster theory reflects a parallel transformation in how geography is theorised. It has moved from being treated as absolute and measurable to being understood as relational, institutional, and now digitally mediated. Rather than becoming outdated, geography has become more complex and dynamic, an active ingredient in regional innovation systems shaped by historical paths, local capabilities, and global linkages (Boschma & Frenken, 2006). Therefore, understanding clusters in the 21st century requires an equally nuanced conception of geography, which recognizes the interplay between space, society, and networks.

While the evolution of cluster theory has progressively expanded the concept of geography from physical proximity to relational and digital space, the strategic and managerial reinterpretation of clusters has emerged in parallel during the 1990s, most prominently advanced by Michael Porter. Unlike earlier geographical or institutional approaches, Porter (1990, 1998) conceptualised clusters as engines of national and regional competitiveness, emphasising their role in enhancing firm productivity,

innovation, and new business formation. However, his conceptual work largely treated geography as a given backdrop, rather than a dynamic or relational construct. This divergence introduced a new challenge to cluster theory: the tension between economic strategy and spatial complexity.

In contrast to earlier approaches that emphasised spatial dynamics, institutional embeddedness, and socio-cultural contexts, Porter repositioned clusters within a strategic and managerial perspective. His seminal works, The Competitive Advantage of Nations (1990) and On Competition (1998), popularised the idea of clusters as geographically proximate groups of interconnected firms, suppliers, service providers, and supporting institutions operating within a particular field. In Porter's model, clusters are not merely a spatial coincidence but a driver of productivity, innovation, and regional competitiveness. This shift brought cluster thinking into the field of business strategy and economic policy, strongly influencing cluster-based development agendas around the world.

At the core of Porter's cluster concept lies the integration of microeconomic competitiveness with regional and national policy objectives. Clusters, in his view, enhance performance by fostering intense local rivalry, stimulating innovation through co-location, and facilitating knowledge spillovers (Porter, 1998). Unlike earlier theoretical models grounded in spatial science or institutional theory, Porter adopted a pragmatic, managerial lens, where the value of proximity lies in its ability to create competitive advantage through specialisation, differentiation, and collaboration (Cortright, 2006; Kosfeld & Mitze, 2023).

Porter's diamond model, which links firm strategy, demand conditions, related and supporting industries, and factor conditions, conceptualises clusters as self-reinforcing systems in which geography serves as a platform for productivity enhancement. This framing helped translate cluster theory into actionable tools for policymakers and business leaders, making it highly influential in shaping regional development strategies across OECD countries and beyond (Ketels, 2013).

Despite its policy traction, the Porterian model has been criticised for its limited treatment of geography as an evolving and relational construct (Asheim et al., 2006; Bathelt, 2005; Marchionni & Oinas, 2023). Scholars argue that while Porter acknowledges co-location, he does not fully engage with the deeper institutional, historical, and socio-spatial dynamics that underpin cluster formation and evolution (Martin & Sunley, 2003; Maskell & Malmberg, 2007). His work tends to view geography as a static container or passive enabler, rather than a dynamic, co-constituted element shaped by networks, norms, and policy regimes (Sharif, 2006; Wieland, 2024).

Moreover, Porter's emphasis on competitiveness has been challenged by evolutionary economic geographers, who highlight the role of path dependence, lock-in, and regional adaptability (Boschma & Frenken, 2006, 2011). From this perspective, clusters are not only the result of strategic design but are deeply shaped by historical contingencies and institutional legacies that constrain or enable innovation (Boschma & Frenken, 2006, 2011; Hassink et al., 2019; Martin & Sunley, 2006, 2011). Critics have also questioned the model's applicability in the digital age, where virtual clusters and networked innovation systems often transcend geographic proximity, demanding a broader understanding of connectivity, mobility, and digital infrastructures (Bathelt & Cohendet, 2014; Götz & Jankowska, 2017; Passiante & Secundo, 2002; Salvador, 2021; Salvador et al., 2013).

The divergence between Porter's strategic framing and the geographic-institutional evolution of cluster theory reveals a core tension in the field: the struggle to balance location-based advantage with the relational and adaptive dynamics of innovation systems. Rather than discarding either perspective, recent scholarship has sought to integrate them by viewing clusters as strategically valuable, but also socially constructed, historically grounded, and increasingly digitally mediated (Asheim et al., 2011; Götz, 2021; Passiante & Secundo, 2002).

The historical and conceptual evolution of cluster theory reveals not a single unified paradigm, but a plurality of perspectives, each one offering valuable insights into the

complex relationship between space, strategy, and innovation. From Marshall's early spatial logic to Porter's competitive reframing, and from the institutional richness of industrial districts to the digital flows of the 21st century, cluster thinking has continuously adapted to changing economic realities (Chu & Hassink, 2022, 2023; Porter & Ketels, 2009; Trippl & Bergman, 2019).

Academic contributions over the past decades have significantly advanced understanding of clusters. These contributions reveal key lessons that invite a more nuanced rethinking of how clusters function in an increasingly interconnected and dynamic world. First, geography continues to matter, not as an isolated spatial factor, but as a relational and embedded dimension shaped by institutional infrastructures, social networks, and regional adaptability (Asheim et al., 2007; Boschma, 2005). Second, strategy and space should not be treated as competing perspectives but as complementary lenses: clusters are simultaneously tools for competitiveness and evolving socio-economic systems with deep local roots and global linkages (Martin & Sunley, 2003; Porter, 1998). Third, the future of cluster theory and policy lies in embracing a hybrid vision that integrates place-based embeddedness with global connectivity, physical co-location with virtual collaboration, and economic performance with institutional and cultural capacities (Bathelt et al., 2004; Cooke et al., 1997).

These insights highlight the need for an adaptive, multi-scalar framework that captures the complexity of innovation ecosystems in both material and digital spaces, where geography is not just a backdrop but a living, flexible, and strategic component of economic development.

## 2.2 Cluster life cycle from static geography to evolutionary dynamics

Early conceptions of industrial clusters were dominated by the benefits of geographic proximity, such as localised knowledge spillovers, cost efficiencies, and co-location economies (Krugman, 1991; Porter, 1998). However, these spatially deterministic views often treated clusters as fixed, static entities. In contrast, the emergence of Cluster Life Cycle

(CLC) theory shifted the analytical focus toward the temporal dynamics of cluster development. Rather than permanent structures, clusters are increasingly understood as adaptive and path-dependent systems that progress through distinct phases: emergence, growth, maturity, and eventually decline or renewal (Martin & Sunley, 2011; Menzel & Fornahl, 2010).

While the CLC approach offers a valuable heuristic for understanding structural transitions in clusters, it has been critiqued for its linearity and determinism. The model implies a fixed developmental trajectory, leaving limited room for recursive dynamics, sudden shocks, or strategic interventions. In response, scholars developed alternative models to better capture the complexities of cluster evolution. Notable among these are the Adaptive Cycle model (Martin & Sunley, 2011), the parameter-based diagnostic model proposed by Ostapenko et al. (2022, 2025), and the empirically grounded renewal model by König & Brenner (2025). These models address structural flexibility, institutional agency, and external shocks, offering a more nuanced interpretation of how clusters transform over time.

This section critically synthesises these theoretical contributions, analysing the mechanisms through which clusters experience not only decline but also resilience and renewal. In doing so, it lays the conceptual foundation for understanding how industrial clusters can reorganise and recover in response to technological disruption and institutional realignment.

### 2.2.1 The cluster life cycle model: structure, limits, and empirical Insights

The four-stage Cluster Life Cycle (CLC) model proposed by Menzel and Fornahl (2010) remains foundational for explaining how clusters evolve. It outlines a sequential progression through emergence, growth, maturity, and either decline or renewal, each associated with distinct shifts in innovation dynamics, institutional structures, and inter-firm networks. In the emergence phase, clusters form through entrepreneurial experimentation and loose, informal networks. Growth follows as firms and institutions organise

themselves around shared technological trajectories. Maturity introduces structural consolidation and incremental innovation, while decline signals rigidification, cognitive lock-in, and weakening competitiveness unless conditions for renewal are activated.

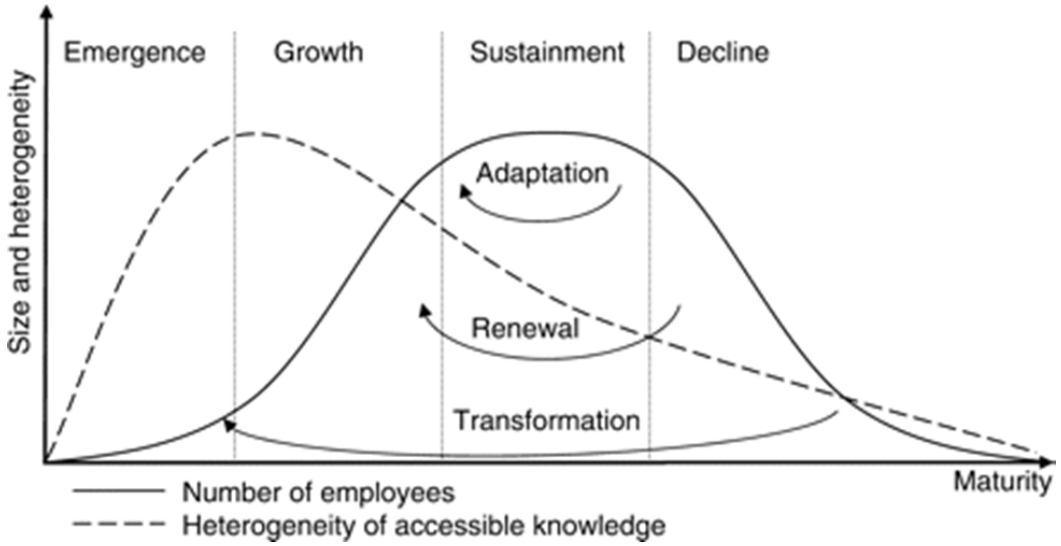


**Figure 2. Cluster Life Cycle model illustrating the evolution of clusters from emergence to maturity, including adaptation, renewal, and transformation pathways (Menzel & Fornahl, 2010).**

This staged progression, as shown in Figure 2, follows a fixed trajectory that may overlook the complex and often non-linear nature of real-world cluster development. One strength of the CLC model is its ability to highlight problems that often emerge during the maturity stage, such as institutional inertia, cognitive lock-in, and declining innovation capacity (Hassink, 2010; Martin & Sunley, 2006; Menzel & Fornahl, 2010). These studies show that while mature clusters benefit from established networks and infrastructures, these same strengths can become rigid structures that hinder adaptability and responsiveness to change. Factors that once supported the success of the cluster, such as close social ties, strong institutions, and a shared knowledge base, can turn into weaknesses when they become too rigid, making it harder for firms to adapt to new technologies or market changes.

This progression has been illustrated in several empirical cases. For example, the Eindhoven region provides a compelling example of cluster renewal: following the downsizing of Philips, the local economy diversified into design and photonics, supported by strong institutional infrastructure and knowledge recombination (Trippl et al., 2015). Such examples point to the importance of adaptive capabilities and institutional flexibility in steering clusters away from decline and towards strategic renewal.

The value of the CLC model lies in its vocabulary and temporal mapping. It provides a diagnostic lens for recognizing the innovation bottlenecks and organisational rigidities that typically emerge in the maturity stage (Hassink, 2010; Menzel & Fornahl, 2010). These include declining absorptive capacity, loss of cognitive diversity, and over-reliance on established technologies. Such issues pose major risks to long-term competitiveness and innovation-led growth.

Despite its analytical strengths, the CLC model has been critiqued for oversimplifying the complexity of real-world cluster dynamics. Martin and Sunley (2011) argue that clusters rarely follow a predictable linear path; instead, they are shaped by recursive processes, external shocks, and heterogeneous institutional responses. Moreover, the model offers limited insight into how clusters actively reconfigure or transition across stages through agency, governance, or policy intervention. As a result, alternative models have emerged to better account for these dimensions of adaptability and transformation.

### 2.2.2 The adaptive cycle model: clusters as complex adaptive systems

Martin and Sunley (2011) explain that clusters may become stuck in old routines, narrow specialisations, and fixed institutional settings, which limit innovation and increases the risk of decline. Jia et al. (2015) also show that in mature clusters, the innovation network can reach a state of balance where learning slows down, knowledge becomes repetitive, and new ideas are harder to develop. As a result, clusters may struggle to respond to changes in the external environment.

Although the CLC model provides valuable insight into these dynamics, its linear conception limits the ability to explain how clusters may recover or transform in response to external shocks or internal crises. To address this limitation, Martin and Sunley (2011) proposed the Adaptive Cycle model, which draws on resilience theory and ecological systems thinking. This model views clusters as complex adaptive systems that move through recurring cycles of exploitation (growth), conservation (maturity), release (crisis or collapse), and reorganisation (renewal).

The Adaptive Cycle model recognises that clusters may not follow a single trajectory but may instead experience multiple cycles, including decline, reconfiguration, and renewal. It also integrates insights from evolutionary economic geography (Boschma & Frenken, 2006), which highlights the importance of path dependence, variety, and historical context in shaping regional development outcomes. From this perspective, decline is not an inevitable outcome of maturity; instead, clusters may adapt by branching into related sectors, integrating external knowledge, or shifting institutional and technological paths (Østergaard & Park, 2015).

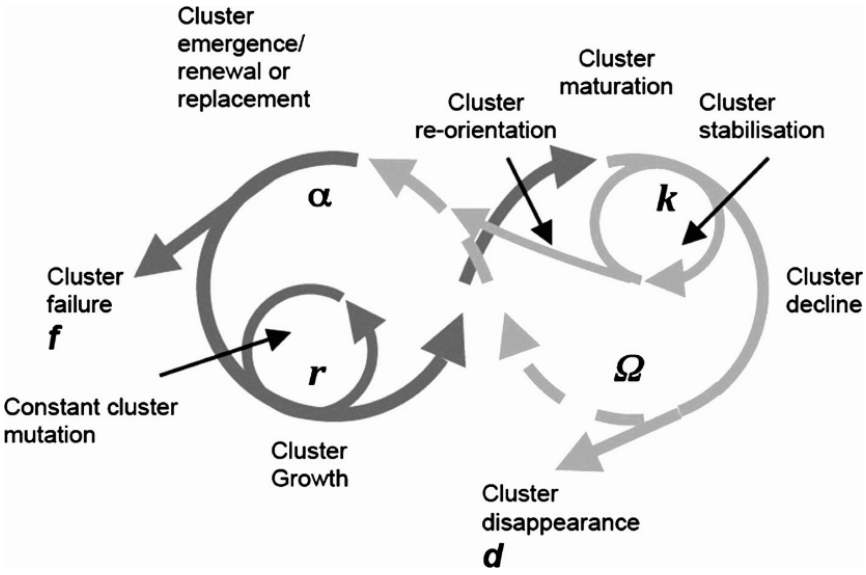


**Figure 3. Adaptive cycle model of cluster evolution (Martin & Sunley, 2011).**

The Adaptive Cycle model (Figure 3) depicts how clusters move through stages of growth, maturity, collapse, and reorganisation. It is supported by empirical work such as Østergaard and Park (2015), who show how repeated technological and economic disruptions, together with cognitive lock-in, technological rigidities, and the exit of focal firms, shifted the North Jutland wireless communication cluster from rapid growth into decline, highlighting how limited adaptive capabilities can block renewal. This perspective underscores that release and reorganisation are not final endpoints but phases that, depending on how they are governed, can either rebuild long-term competitiveness or accelerate decline.

The Adaptive Cycle thus widens analytical scope by framing decline as a normal element of evolutionary development rather than simple failure. It captures systemic and temporal complexity, making it useful for interpreting clusters exposed to fast technological change, environmental shocks, or geopolitical disruptions. At the same time, its high level of abstraction and lack of clearly specified indicators mean that, compared with more diagnostic models, it offers limited practical guidance on how to design interventions or empirically trace transitions between stages.

### 2.2.3 Path-based cluster dynamics: the Ostapenko et al. model

Building on this conceptual foundation, Ostapenko et al. (2022, 2025) propose an enhanced model of cluster dynamics that expands on the Adaptive Cycle perspective developed by Martin and Sunley (2011). Their model introduces a path-based terminology that captures the nuanced stages of cluster evolution, including emergence, development, sustainment, decline, and transformation (Ostapenko et al., 2022, 2025). Unlike linear models, this approach provides a practical method for identifying a cluster's position in its life cycle and understanding the conditions that shape transitions between stages. This is particularly relevant for digitally transforming clusters, where strategic renewal often follows non-linear and data-driven trajectories.

To identify a cluster's position within its evolutionary path, the Ostapenko et al. model employs seven diagnostic parameters, grounded in established cluster evolution literature (Menzel & Fornahl, 2010; Ostapenko et al., 2022; Trippl et al., 2015). These parameters collectively offer a practical diagnostic toolkit for mapping both internal dynamics and external positioning. They include:

1. Cluster Identity
2. Number of Firms
3. Number of Employees
4. Innovation Level
5. Network Structure
6. Policies and Regulations
7. External Market Engagement

In digitally connected ecosystems, such parameters can increasingly be informed by real-time data flows, which enhances their analytical utility for monitoring cluster dynamics and renewal conditions.

What distinguishes this model is its integration of resilience theory and evolutionary economic geography (EEG). By adopting the Adaptive Cycle logic (Martin & Sunley, 2011) and EEG principles such as path dependence, variety, and historical contingency (Boschma & Frenken, 2006; Trippl et al., 2015), the concept accounts for non-linear trajectories, the influence of external shocks, and the institutional co-evolution. This helps address criticisms of the CLC model, such as its limited attention to agency and institutional change (Hassink et al., 2019). Crucially, the Ostapenko et al. model incorporates the transformative potential of digital infrastructures, which increasingly serve as enablers of new evolutionary paths and strategic renewal.

The model's practical value is illustrated through empirical applications, notably the Bordeaux and Napa Valley wine clusters. These case studies reveal that clusters may

simultaneously exhibit stability and transformation, particularly when technological renewal and diversification evolve alongside a mature core industry (Ostapenko et al., 2025). This supports the view that cluster maturity does not prevent adaptability; rather, strategic renewal can emerge through intentional repositioning (Kohtamäki et al., 2025; Østergaard & Park, 2015; Trippl et al., 2015). To conceptualise these diverse trajectories, Ostapenko et al. (2022) developed a visual model of cluster dynamics.

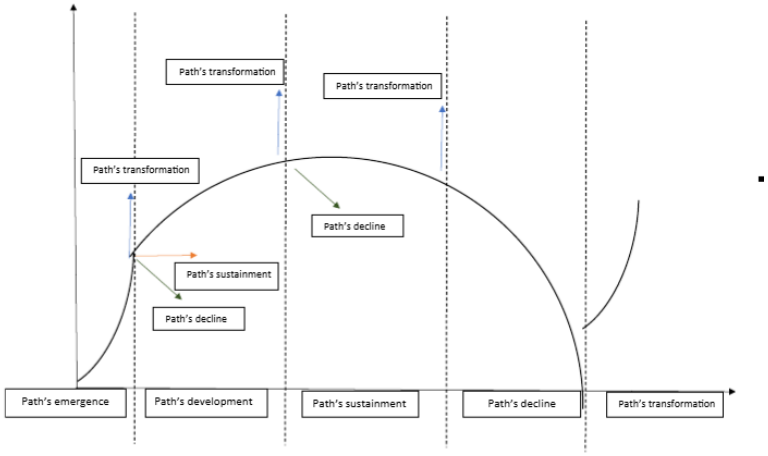


**Figure 4. Cluster dynamics and path-based evolution in the Cluster Life Cycle framework (Ostapenko et al., 2022).**

This model captures the recursive and non-linear nature of cluster evolution. Rather than presenting a fixed path, it allows for re-entry into earlier stages, avoiding expected transitions, and hybrid configurations. Such flexibility is essential for reflecting the multidimensional realities faced by clusters navigating digital disruption and sectoral convergence (see Figure 4).

A key contribution of the Ostapenko et al. approach is its ability to integrate internal characteristics with broader contextual factors like policy environments, institutional flexibility, and market trends. This enables a more holistic and nuanced diagnosis of cluster trajectories. Unlike static or linear frameworks, this model captures the complexity of cluster evolution by allowing for diverse and non-linear development paths. It is particularly relevant for digitally transforming clusters, where renewal can emerge through

mechanisms such as platform-based coordination, data-driven governance, or algorithmically informed strategic adaptation.

The model operationalises cluster analysis through measurable indicators that can function as early warning signals for path shifts. By combining internal factors, such as innovation levels and network density, with external variables like regulatory environments and market trends, it facilitates targeted assessment and timely intervention. In digital contexts, the availability of real-time monitoring further enhances the model's responsiveness and strategic value.

Perhaps the most distinctive strength of this model is its flexibility in accommodating diverse development patterns. Clusters may exhibit features of different stages simultaneously; for instance, a mature industry core may co-exist with emerging niche sub-clusters. This pluralism clearly illustrated in empirical cases: the Bordeaux wine cluster combines deep tradition with innovations in tourism and sustainability, while Napa Valley leverages digital branding and technological tools to renew its competitive edge (Ostapenko et al., 2025). These cases show that cluster renewal does not require a complete structural change; it can emerge through targeted adaptation, strategic repositioning, or governance realignment.

In sum, the Ostapenko et al. model offers a robust, empirically grounded, and policy-relevant extension of earlier life cycle theories. Its main contributions include a non-linear understanding of cluster dynamics, a diagnostic toolkit based on measurable parameters, and the integration of institutional and digital dimensions. These features make it particularly relevant for analysing complex, adaptive trajectories in mature or digitally transforming clusters. Nevertheless, the model's practical application requires access to detailed, context-specific data, and its diagnostic depth may pose challenges for prioritising interventions. However, the increasing availability of digital monitoring tools and real-time data analytics offers promising possibilities to mitigate these constraints and enhance the model's strategic utility.

### 2.2.4 Empirical insights on cluster renewal: König and Brenner's multi-dimensional approach

While Martin and Sunley (2011) emphasise the recursive dynamics of cluster development, recent empirical work by König and Brenner (2025) has advanced the life cycle perspective through a meta-analysis of 69 cluster case studies across industries and geographies. Their findings identify three multi-dimensional mechanisms that shape cluster trajectories:

- Preconditions (e.g., labour market structure, firm size distribution)
- Triggering events (e.g., regulatory change, disruptive technologies)
- Self-reinforcing processes (e.g., spin-offs, knowledge flows, cross-cluster linkages)

This concept moves beyond a linear or deterministic view by highlighting that decline and renewal are not opposite poles, but interactive outcomes shaped by timing, institutional adaptability, and external shocks. As visualised in Figure 5, events act as inflection points that either reinforce decline or enable renewal depending on the cluster's adaptive capacity.

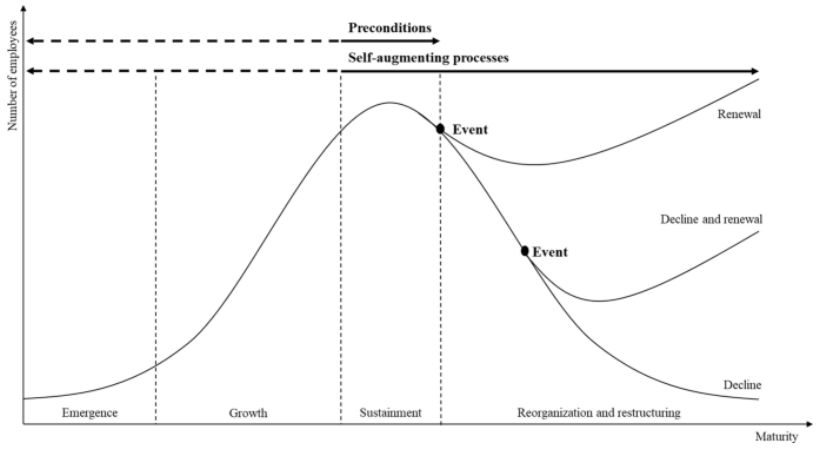


**Figure 5. Stages of cluster evolution illustrating decline and renewal pathways (König & Brenner, 2025).**

This model complements earlier conceptual approaches by showing how renewal is not merely reactive but can be strategically cultivated through proactive governance, institutional learning, and global connectivity (Bathelt & Cohendet, 2014; König & Brenner, 2025).

**Preconditions** refer to the structural and institutional context in place before change occurs, such as labour market characteristics, institutional density, firm demographics, and forms of lock-in. These conditions shape, but do not determine, how a cluster responds to disruption.

**Triggering events** are external shocks, including policy reforms, technological shifts, or firm relocations, that expose internal vulnerabilities within a cluster. Importantly, the same shock may lead to renewal in one context but decline in another, depending on underlying preconditions and adaptive capacity.

**Self-augmenting processes** are feedback loops that can accelerate either renewal or decline. These may include innovation, diversification, capital inflows, or conversely, disinvestment and brain drain. Such processes are not merely outcomes of change but active drivers of cluster transformation.

Overall, this model advances cluster theory in three keyways. First, it moves beyond linear life-cycle models by framing decline and renewal as path-dependent processes shaped by interactions between internal structures and external forces. Second, it offers practical policy entry points by helping identify which conditions are modifiable through targeted intervention. Third, it highlights the importance of multi-actor governance, recognising that coordinated action among firms, universities, and public authorities is essential for successful cluster renewal.

Despite its strengths, the model is not without limitations. It remains largely descriptive rather than predictive and does not clearly define tipping points between decline and

renewal. The difference between preconditions and processes can be hard to distinguish in practice, and issues of agency and power dynamics are not examined in detail, especially in situations where some organisations dominate decision-making or have much stronger resources than others. Additionally, its empirical foundation lies mostly in Global North contexts, with limited testing in emerging economies. Still, König and Brenner's contribution mark a major step in bridging theory and practice, offering both scholars and policymakers a robust tool to interpret and shape cluster trajectories.

While König and Brenner's model is rooted in empirical diagnosis, the Adaptive Cycle model by Martin and Sunley (2011) offers a conceptual view of cluster evolution, inspired by resilience theory through its four recurring phases (exploitation, conservation, release, and reorganisation) that capture the cyclical and non-linear nature of cluster change. This model treats clusters as complex adaptive systems, where resilience and the capacity to reorganise determine long-term survival.

The key distinction lies in explanatory focus; the Adaptive Cycle provides a high-level conceptual narrative of change over time, whereas König and Brenner offer a diagnostic lens that categorises real-world evidence into actionable drivers and conditions. They also differ in how they handle agency. Martin and Sunley embed agency in system resilience, while König and Brenner, though not theory-heavy on agency, provide more explicit policy levers and intervention points, particularly through modifiable preconditions.

Nevertheless, both models reject deterministic views and highlight the role of external shocks, internal structures, and the capacity for renewal. Used together, the Adaptive Cycle can frame macro-level dynamics, while König and Brenner's model can guide case-specific strategy and intervention.

Despite rich theoretical developments in cluster evolution and renewal, existing models struggle to address the digitally mediated, rapidly shifting dynamics of contemporary clusters. Particularly absent are integrated operational frameworks that link digital

capabilities, institutional readiness, and strategic governance. This study proposes the DICAAAP model to fill this gap, offering a toolkit-oriented framework to diagnose, activate, accelerate, and adapt digital industrial cluster transformation.

## 2.3 Digital transformation and digital industrial clusters (DIC)

This section builds the conceptual basis for the proposed DICAAAP framework by synthesizing emerging literature on digital transformation, digital strategy, and Digital Industrial Clusters (DIC).

### 2.3.1 Digital transformation

Digital transformation refers to a broad and ongoing process through which digital technologies fundamentally reshape organisational structures, strategies, and value creation mechanisms, extending beyond isolated technology adoption to affect how firms operate, compete, and evolve over time (Bharadwaj et al., 2013; Verhoef et al., 2021; Vial, 2019). It is commonly distinguished from digitisation, understood as turning analogue information into digital formats, and from digitalisation, which refers to the use of digital technologies to improve existing processes and activities (Dąbrowska et al., 2022; Piepponen et al., 2022). In contrast, digital transformation involves a systemic reconfiguration of organisational logics, routines, and industrial arrangements, often including changes in cognition, governance, and strategic orientation (Hanelt et al., 2021).

The literature emphasises that digital transformation is typically a gradual and path-dependent process, as firms increasingly build their strategies, operations, and business models around emerging digital capabilities (Alnuaimi et al., 2022). At the same time, environmental disruptions and external shocks may accelerate transformation, prompting rapid strategic shifts and organisational reconfiguration, as observed, for example, during the COVID-19 pandemic (Clauss et al., 2022). Across industries, digital technologies shape decision-making, innovation processes, and value-chain and supply-chain configurations, reinforcing the view of digital transformation as a holistic organisational

change rather than a single technological intervention (Di Vaio et al., 2021; Urbinati et al., 2019).

Conceptually, research on digital transformation builds on multiple theoretical perspectives, including the resource-based view, organisational change, business model innovation, and, most prominently, dynamic capabilities. Many studies argue that digital technologies simultaneously create new opportunities for value creation and expose firms to heightened competitive pressures, thereby requiring continuous sensing, seizing, and reconfiguring of resources and routines (Hanelt et al., 2021; Verhoef et al., 2021). From this perspective, digital transformation is understood as a continuous, process-centric phenomenon involving changes across organisational levels, practices, and structures, rather than a one-time strategic initiative.

Importantly, the literature consistently highlights that digital transformation does not happen without clear strategic direction. Digital strategy provides the directional orientation through which firms articulate digital ambitions, allocate resources, and prioritise investments in digital capabilities (Bharadwaj et al., 2013; Kohtamäki et al., 2025). In this way, digital strategy helps make digital transformation possible by shaping its scope, pace, and how it becomes part of everyday organisational life. However, while digital strategy reflects intentional planning and strategic decision-making, digital transformation extends beyond strategy implementation to incorporate broader and often emergent reconfigurations of organisational structures, routines, and value creation logics (Hanelt et al., 2021; Vial, 2019).

Building on this foundation, the literature has expanded to examine specific areas where digital transformation takes shape, including digital strategy, digital business model innovation, and digital servitization. These research streams highlight how digital technologies reshape strategic decision-making, value creation and capture mechanisms, and organisational forms, thereby enabling new trajectories of organisational renewal (Bharadwaj et al., 2013; Verhoef et al., 2021). Together, they emphasise that digital

transformation is not limited to firm-level optimisation but also intersects with broader industrial and ecosystem dynamics, including cluster-level coordination and inter-organisational collaboration.

### 2.3.2 Digital transformation beyond the firm: from digital strategy to DIC

Although digital strategy provides firms with intentional direction and resource allocation for digital initiatives, an expanding body of research argues that the outcomes of digital transformation cannot be fully explained at the level of a single firm (Bharadwaj et al., 2013; Verhoef et al., 2021; Vial, 2019; Yoo et al., 2012). As digital technologies reshape value creation, coordination, and innovation processes, firms become embedded in complex networks of suppliers, customers, complementors, and institutional actors, so that strategic outcomes depend on multi-actor alignment rather than isolated organisational optimisation (Verhoef et al., 2021; Vial, 2019; Yoo et al., 2012).

This shift challenges traditional strategy perspectives that assume relatively stable firm boundaries and hierarchical control (Bharadwaj et al., 2013). Digital technologies enable modular architectures, data-driven coordination, and real-time interaction across organisational interfaces, blurring lines between internal and external activities and redistributing decision-making authority (Yoo et al., 2012). As a result, strategic value increasingly arises from inter-organisational collaboration, shared digital infrastructures, and collective capability development, while the effectiveness of a firm's digital strategy depends on the strategic orientations and digital readiness of the actors on which it relies (Helfat & Raubitschek, 2018; Jacobides et al., 2018; Verhoef et al., 2021).

Reflecting this shift, recent strategy research emphasises ecosystem-level coordination as a central dimension of digital transformation. Kohtamäki et al. (2025), based on a bibliometric analysis of 626 high-quality studies, show that digital transformation, digital strategy, and digital business model innovation constitute interrelated perspectives that converge around networked and ecosystem forms of organising. Relatedly, Helfat and Raubitschek (2018) highlight ecosystem orchestration, sensing, and coordination

capabilities as critical for navigating digitally enabled interdependencies, while Jacobides et al. (2018) stress the role of governance structures in shaping value creation and capture across ecosystems.

These coordination challenges are especially pronounced in mature industrial clusters, which are characterised by geographic concentration, dense inter-firm networks, and strong institutional embeddedness. Classical cluster theory highlights the advantages of proximity, including knowledge spillovers, specialised labour pools, and relational trust (Marshall, 1920; Porter, 1990), whereas evolutionary cluster research shows that mature clusters are also susceptible to lock-in, stagnation, and declining adaptability due to path dependence and entrenched coordination patterns (Boschma, 2015; Hassink, 2010; Martin & Sunley, 2011). Therefore, digital transformation does not replace traditional cluster dynamics but reconfigures them, adjusting the balance between local face-to-face interaction and digitally mediated coordination within and across clusters (Bathelt & Cohendet, 2014; Boschma & Frenken, 2011).

Digital transformation challenges the spatial logic of clustering without rendering geography irrelevant. Proximity theory conceptualises proximity as multidimensional, encompassing cognitive, social, organisational, and institutional dimensions alongside geographic proximity (Boschma, 2005). From this perspective, digital infrastructures do not eliminate clustering but reconfigure how non-spatial forms of proximity are activated and maintained across distance, enabling clusters to extend coordination beyond physical co-location while remaining anchored in place-based capabilities and institutions (Bathelt & Li, 2014; Boschma & Frenken, 2011).

As a result, cluster competitiveness increasingly depends on integrating firm-level digital strategies into coherent, cluster-level transformation trajectories. This shift motivates the concept of the Digital Industrial Cluster (DIC), which conceptualises clusters as digitally mediated ecosystems rather than purely geographically bounded agglomerations, where digital platforms, shared data infrastructures, and coordinated governance

mechanisms support inter-firm collaboration, innovation, and strategic renewal across organisational and regional boundaries (Helfat & Raubitschek, 2018; Kohtamäki et al., 2025; Yoo et al., 2012).

From this perspective, Digital Industrial Clusters address the limits of focusing only on single firms' digital strategies in a world of growing interdependence and complexity. They provide a meso-level strategic approach through which fragmented digital strategies can be aligned, synergies can be created, and shared skills and resources can be built up, which is especially important for mature industrial clusters facing risks of stagnation or decline (Hassink et al., 2019; Jacobides et al., 2018; Martin & Sunley, 2011; Verhoef et al., 2021).

Accordingly, this thesis builds on the Digital Industrial Cluster concept to develop the DICAAAP framework, which conceptualises digital transformation as a staged, cluster-level process involving digitalisation, agglomeration dynamics, strategic alignment, and platform-mediated coordination. Drawing on insights from evolutionary economic geography and digital transformation research, the framework explains how such processes can support cluster renewal, cross-regional expansion, and sustained competitiveness in contexts shaped by technological change and institutional path dependence (Boschma, 2015; Kohtamäki et al., 2025).

### 2.3.3 DIC: concept, mechanisms, and life cycle dynamics

The concept of the Digital Industrial Cluster (DIC) builds on classical cluster theory while explicitly incorporating the structural effects of digital transformation and Industry 4.0 technologies on coordination, innovation, and value creation (Fernandez-Escobedo et al., 2024; Fernandez-Escobedo & Cuevas-Vargas, 2023). In this thesis, DIC refers to the conceptual model proposed in this literature stream and is treated as a target configuration rather than as a generic label for all digitally connected clusters.

Traditional cluster theory explains competitive advantage through geographic proximity, dense inter-firm networks, specialised labour markets, and institutional embeddedness, which together facilitate knowledge spillovers and collective learning (Marshall, 1920; Porter, 1990). Evolutionary perspectives extend this view by emphasising that clusters are dynamic systems whose trajectories are shaped by path dependence and processes of renewal or decline over time (Martin & Sunley, 2011; Menzel & Fornahl, 2010).

Recent research argues that digitalisation reconfigures these mechanisms, giving rise to the Digital Industrial Cluster as a distinct organisational and policy concept. Fernandez-Escobedo and Cuevas-Vargas (2023) conceptualise the DIC as a post-pandemic response to heightened uncertainty, supply-chain fragility, and uneven digital readiness, highlighting its role in enhancing resilience, inclusiveness, and coordinated innovation. Fernandez-Escobedo et al. (2024) further position the DIC as a new agglomeration model for the industry 4.0 era, arguing that digital infrastructures, platforms, and data-driven coordination increasingly complement, and in some cases partially substitute, physical proximity as sources of agglomeration advantages.

From this perspective, a DIC can be defined as industrial agglomerations in which coordination, innovation, and collective value creation are increasingly mediated by shared digital infrastructures, Industry 4.0 technologies, and coordinated governance arrangements, enabling both local embeddedness and cross-regional connectivity (Fernandez-Escobedo et al., 2024; Fernandez-Escobedo & Cuevas-Vargas, 2023; Kohtamäki et al., 2025). Therefore, digital transformation does not eliminate spatial clustering but reconfigures it, modifying how knowledge circulates, how coordination is achieved, and how value is collectively created and captured (Boschma & Frenken, 2011; Yoo et al., 2012).

The literature identifies three core structural features that differentiate DIC from traditional industrial clusters. First, DIC are built around Industry 4.0 technologies such as the Internet of Things, data analytics, cyber-physical systems, automation, and cloud computing, whose strategic value lies not in any single technology but in how these tools are

integrated into shared coordination systems that enable clusters to operate beyond local spatial boundaries (Fernandez-Escobedo et al., 2024).

Second, shared digital infrastructures such as platforms, standardised interfaces, and data systems form the foundation of DIC (Fernandez-Escobedo & Cuevas-Vargas, 2023). These systems support coordination, knowledge exchange, and innovation across firms and regions, while their design influences access, participation, and value creation within the cluster, making governance a central concern rather than a purely technical issue (Fernandez-Escobedo & Cuevas-Vargas, 2023).

Third, DIC depend on multi-level governance, since digital coordination concentrates control over data, standards, and interfaces. Public authorities, intermediaries, platform operators, and industry associations help set interoperability standards, build skills, support SME participation, and mitigate power asymmetries, whereas weak or fragmented governance may allow digital infrastructure to reinforce dependency or exclusion instead of enabling collective upgrading (Fernandez-Escobedo et al., 2024).

Taken together, these features frame DIC as intentionally designed ecosystems that rely on policy support, institutional capacity, and sustained investment in technical and organisational infrastructures, providing the basis for their role in cluster renewal. They also underline that the effectiveness of DIC depends not only on technological deployment but on how digital infrastructures and governance arrangements are aligned with existing regional capabilities and industrial trajectories.

#### 2.3.3.1 Core mechanisms of DIC

In Digital Industrial Clusters, key digitally enabled processes play a central role. First, knowledge spillovers increasingly occur through digital platforms, data analytics, and virtual collaboration tools, allowing specialised knowledge to circulate across organisations and regions while still staying rooted in a specific industry (Bathelt & Cohendet, 2014; Fernandez-Escobedo et al., 2024). Second, coordination mechanisms shift from

predominantly informal, proximity-based interaction toward increasingly hybrid forms that combine trust-based relations with formal digital standards, interfaces, and data governance structures (Fernandez-Escobedo & Cuevas-Vargas, 2023; Jacobides et al., 2018).

Third, building shared capabilities becomes an important task in Digital Industrial Clusters. Digital transformation calls for skills and resources such as data analytics, interoperability, cybersecurity, and digital service development, which many firms, especially SMEs, cannot easily develop on their own (Verhoef et al., 2021). DIC can help close these gaps by giving firms access to common digital infrastructures and joint support activities, so that more actors are able to take part in digital initiatives (Fernandez-Escobedo & Cuevas-Vargas, 2023).

Finally, governance mechanisms play a central role, as DIC require explicit rules for platform participation, data sharing, and value appropriation to prevent digitalisation from reinforcing existing power imbalances (Fernandez-Escobedo et al., 2024; Jacobides et al., 2018).

At the same time, the policy logic behind DIC introduces governance tensions. Platform-based coordination may amplify asymmetric power, especially when data control and standards-setting are concentrated among platform orchestrators or dominant firms (Coe & Yeung, 2015; Srnicek, 2017). Platformisation raises questions of access, interoperability, data sovereignty, and value capture, and in cluster contexts these tensions directly shape whether SMEs participate, whether trust can be sustained, and whether cross-regional expansion leads to inclusive renewal or new dependency structures (Fernandez-Escobedo & Cuevas-Vargas, 2023; Van Dijck et al., 2018).

#### 2.3.3.2 DIC and life cycle dynamics

These limitations become even more evident when Digital Industrial Clusters are considered through the lens of life cycle dynamics. Existing life cycle models describe how clusters move through phases of emergence, growth, maturity, and potential decline, and recent work shows how digitalisation can act as a trigger, indicator, or enabler of renewal within these trajectories (Hassink, 2010; König & Brenner, 2025; Menzel & Fornahl, 2010; Ostapenko et al., 2022). However, the literature still offers limited insight into the concrete processes through which mature clusters reorganise their coordination structures, build shared digital capabilities, and institutionalise new governance arrangements to evolve into functioning DIC, which is the focus of the following subsection.

Integrating the DIC concept with cluster life cycle theory highlights its relevance for cluster renewal. Life cycle models describe how clusters evolve through emergence, growth, maturity, and potential decline, with mature clusters facing risks of lock-in and reduced adaptability (Hassink, 2010; Martin & Sunley, 2011; Menzel & Fornahl, 2010). Digital transformation can either reinforce stagnation when adopted superficially or enable renewal when strategically aligned and collectively governed (Boschma, 2015).

This dual potential closely mirrors Ostapenko et al.'s (2022, 2025) adaptive cluster dynamics model, in which digitalisation operates as a key indicator shaping whether a cluster moves toward decline or transformation. Their model includes factors such as innovation intensity, network structure, and external market engagement, all of which are strongly affected by digital capabilities. In addition, König and Brenner (2025) identify technological shifts as crucial triggers that interact with existing institutional and structural conditions to determine whether clusters deepen decline or initiate self-renewal. From this perspective, digital transformation is not a technical trend but a context-sensitive enabler whose outcomes depend not only on internal capabilities, but also on how actors interact within the cluster and with external partners (Boschma, 2015; Hassink, 2010; König & Brenner, 2025; Martin & Sunley, 2011).

Fernandez-Escobedo et al. (2024) argue that Digital Industrial Clusters (DIC) can function as a renewal mechanism by enabling clusters to recombine existing industrial strengths with new digital capabilities and Industry 4.0 technologies. Through shared digital platforms and coordinated strategies, DIC allows mature clusters to extend beyond local boundaries, diversify into related activities, and enhance resilience against external shocks.

This view is consistent with work on adaptive cluster dynamics and technological triggers, which shows that digitalisation can act both as a catalyst and as a self-reinforcing process when institutional flexibility and absorptive capacity are in place (König & Brenner, 2025; Ostapenko et al., 2022, 2025). The role of strategic coordination and reconfiguration is also reflected in the work of Kohtamäki et al. (2025), who highlight how digital servitisation enables mature clusters to reorient towards new value propositions. Together, these perspectives support the view that DIC are not merely technological upgrades, but complex institutional and strategic transformations embedded within broader cluster dynamics (Trippl et al., 2015).

#### 2.3.3.3 Implications for strategic coordination and renewal

From a strategic perspective, Digital Industrial Clusters highlight the limitations of firm-centric digital strategy. While firms initiate digital transformation through strategic intent, cluster-level outcomes depend on the alignment of strategies, capabilities, and governance across heterogeneous actors embedded in a shared institutional context (Kohtamäki et al., 2025; Verhoef et al., 2021). DIC therefore operates as meso-level coordination structures, enabling collective action, reducing coordination costs, and supporting long-term renewal across the cluster life cycle.

Accordingly, this thesis builds on the DIC concept as developed by Fernandez-Escobedo and Cuevas-Vargas (2023) and Fernandez-Escobedo et al. (2024) to advance the DICAAAP framework, which conceptualises digital transformation as a staged, cluster-level process integrating digitalisation, agglomeration dynamics, strategic alignment,

and platform-mediated coordination. By embedding digital transformation within cluster life cycle dynamics, the framework explains how mature industrial clusters can leverage digital technologies to achieve renewal, resilience, and cross-regional expansion.

Three theoretical traditions underpin the DIC concept. Evolutionary economic geography explains DIC as mechanisms of path reconfiguration, where digital infrastructures enable new knowledge trajectories and extra-local networks that help clusters escape lock-in (Boschma & Frenken, 2006; Menzel & Fornahl, 2010; Trippl et al., 2015). Innovation systems theory frames DIC as reconfigured regional innovation systems in which collaboration depends increasingly on interoperability, platform coordination, and institutional alignment, rather than solely on geographic proximity (Fernandez-Escobedo & Cuevas-Vargas, 2023). Digital platform theory highlights how platforms shape access, standardisation, and value capture, creating both opportunities for scaling and risks of dependency, which makes platform governance a strategic concern for digital cluster renewal (Srnicek, 2017).

To date, there is not an empirically grounded, cluster-level framework that (a) treats digital industrial clusters as renewal mechanisms within the CLC, and (b) provides a staged, diagnostic, and governance-oriented pathway for their activation and scaling.

Empirical initiatives such as European Digital Innovation Hubs, Korea's Smart-Green Industrial Complexes, and Italy's digitally oriented industrial programmes show that DIC-like systems can support upgrading and renewal when public investment, local absorptive capacity, and coordinated governance are in place (Choi & Lee, 2023; European Investment Bank, 2021; Fernandez-Escobedo & Cuevas-Vargas, 2023; OECD, 2021). At the same time, implementation problems, such as institutional fragmentation, digital capability gaps, and platform dependency, show that digital infrastructures alone do not guarantee inclusive transformation (Fernandez-Escobedo & Cuevas-Vargas, 2023; Panori, 2024).

Overall, existing DIC research explains what digital industrial clusters are, why they matter, and which structural components they require, but offers far less clarity on the process dynamics through which a mature cluster transitions into a functioning DIC, including how actors are mobilised around a shared digital renewal purpose, how critical mass and participation are built, and how governance and learning routines become institutionalised over time (Fernandez-Escobedo & Cuevas-Vargas, 2023; Menzel & Fornahl, 2010). Current models are strong on conceptualisation and diagnosis, yet they provide limited guidance on how digital transformation should be diagnosed, activated, scaled, and institutionalised as part of a governed renewal pathway at the cluster level. This operational gap is particularly important for mature industrial clusters and motivates the DICAAAP framework introduced in the next chapter, which offers a staged and governance-oriented pathway, namely activation, acceleration, and adaptation, for digital cluster renewal and cross-regional scaling.

Chapter 2 has established the theoretical basis for treating Digital Industrial Clusters (DIC) as a renewal mechanism within cluster life cycle dynamics and for framing digital transformation as a cluster-level coordination and governance challenge. At the same time, the literature provides limited process guidance on how mature clusters move from diagnostic recognition to scaled implementation and institutionalisation. To address this operational gap, Chapter 3 introduces the DICAAAP framework as a staged pathway for activating, accelerating, and adapting digital coordination in support of cluster renewal and cross-regional scaling.

# 3 Theoretical framework of DICAAAP

## 3.1 Conceptual foundations of the DICAAAP framework

This chapter introduces DICAAAP as the thesis' central conceptual framework, designed to address the gaps identified in the literature review. The framework proposes a process-oriented, governance-aware pathway for renewing mature industrial clusters through digital transformation (König & Brenner, 2025; Martin & Sunley, 2011).

Digital transformation can deepen path dependencies (accelerating stagnation) or enable renewal through new capabilities and expansion trajectories (Boschma, 2015; Hassink, 2010). Rather than viewing digitalisation as firm-level technology adoption, DICAAAP conceptualises digital transformation as a collective coordination challenge embedded within cluster life cycle dynamics and shaped by governance arrangements (Bathelt & Cohendet, 2014; Dąbrowska et al., 2022).

Platforms and data tools function as coordination technologies whose effects depend on governance design and collective perception (Jacobides et al., 2018). This positioning aligns with ecosystem reconfiguration perspectives rather than purely technological upgrade narratives (Hanelt et al., 2021; Kohtamäki et al., 2025).

The DICAAAP framework conceptualises Digital Industrial Cluster (DIC) formation through three stages:

- Activation: Shared diagnosis of life cycle position and coordination gaps
- Acceleration: Scaling shared digital capabilities and governance
- Adaptation: Institutionalising coordination routines for sustained renewal

Unlike descriptive typologies, DICAAAP is explicitly diagnostic and governance oriented. It identifies clusters' life cycle position, reveals coordination/governance failures constraining digital renewal, and supports managers/policymakers in sequencing

interventions for genuine transformation rather than incremental digitalisation (Hassink et al., 2019; Verhoef et al., 2021).

This chapter operationalises the framework for empirical application to Energy Vaasa. In this thesis, the DIC represents the transformation outcome, while DICAAAP specifies the staged governance pathway through which a mature cluster can move toward that outcome.

## 3.2 Literature integration

The literature review identified parallel theoretical streams that are essential for understanding cluster renewal yet remain weakly integrated. DICAAAP synthesises these contributions into a unified governance framework that connects diagnosis, coordination, and renewal over time.

Table 2 synthesises the core theoretical streams informing DICAAAP and illustrates how the framework integrates their complementary strengths while addressing critical gaps in process guidance and governance. Cluster life cycle theory provides strong diagnostic foundations but limited operational pathways; evolutionary economic geography explains path dynamics without offering intervention logic; digital transformation research illuminates ecosystem coordination but under-specifies cluster-level application; and Digital Industrial Cluster literature clarifies end-states without detailing transformation processes. By integrating these perspectives, DICAAAP reframes digital cluster renewal as a staged and governed process rather than a descriptive condition or isolated technological shift.

While traditional Cluster Life Cycle (CLC) models describe structural evolution across emergence, growth, maturity, and decline, they largely remain descriptive and do not specify governance-oriented mechanisms through which mature clusters can strategically initiate renewal. DICAAAP extends this perspective by embedding digital transformation within lifecycle dynamics as an intentional and staged coordination process. Rather than observing lifecycle progression, the framework conceptualises renewal as an

actively governed sequence of diagnostic alignment, orchestration, scaling, and institutionalisation. In doing so, it shifts the analytical focus from passive evolution to governance-driven digital renewal in mature industrial clusters.

**Table 2.** Core theoretical streams and DICAAAP integration

| Theoretical stream | Contribution | Limitations | How DICAAAP extends it |
|---|---|---|---|
| **Cluster life cycle theory** (Menzel & Fornahl, 2010; Martin & Sunley, 2011) | Temporal evolution of clusters; maturity risks; renewal. | Strong at diagnosis, limited guidance on governing digital renewal in practice | Translates the renewal imperative into a staged cluster-level coordination pathway |
| **Evolutionary economic geography** (Boschma & Frenken, 2006; Trippl et al., 2015) | Path dependence, branching, recombination, and the role of agency | Explains evolutionary trajectories more than the design and sequencing of policy or governance interventions. | Conceptualises digital transformation as a path-shaping process conditional on coordinated governance |
| **Adaptive & diagnostic renewal models** (Martin & Sunley, 2011; Ostapenko et al., 2022; König & Brenner, 2025) | Non-linearity in cluster evolution, renewal drivers, and diagnostic parameters | Emphasis on diagnosis and narratives without a staged, operational governance pathway | Converts renewal conditions and drivers into Activation, Acceleration, Adaptation stages |
| **Digital transformation & ecosystem governance** (Vial, 2019; Verhoef et al., 2021; Kohtamäki et al., 2025) | Systemic change, orchestration, interdependence across actors | Under-specifies clusters as meso-level units with institutional thickness | Anchors ecosystem orchestration and governance explicitly at the cluster level |
| **Platform governance perspectives** (Srnicek, 2017; Van Dijck et al., 2018) | Platforms as coordination and governance infrastructures shaping access, standards, and value capture | Weakly connected to life cycle renewal and spatial embeddedness | Integrates platform governance concerns into cluster-level renewal and coordination dynamics |
| **Digital Industrial Cluster literature** (Fernandez-Escobedo & Cuevas-Vargas, 2023; Fernandez-Escobedo et al., 2024) | What DIC are and why they matter | Lacks transformation process logic. | Provides the staged transformation pathway for DIC formation in mature clusters |

Building on this synthesis, the following section introduces DICAAAP as a staged pathway through which digital cluster transformation is activated, accelerated, and adapted over time.

## 3.3 DICAAAP as a staged pathway of cluster-level transformation

DICAAAP conceptualises digital transformation as a staged coordination pathway rather than a checklist, structured around three interdependent stages: Activation, Acceleration, and Adaptation, through which digital potential is translated into sustained cluster renewal. These stages are analytically distinct yet empirically recursive, reflecting the non-linear and path-dependent nature of cluster evolution (Boschma & Frenken, 2006; Trippl et al., 2015). While clusters may occupy more than one stage simultaneously, sustained renewal typically requires progress across all three stages; however, clusters often move unevenly and partially across them, especially when mobilisation or scaling is not followed by institutionalisation.

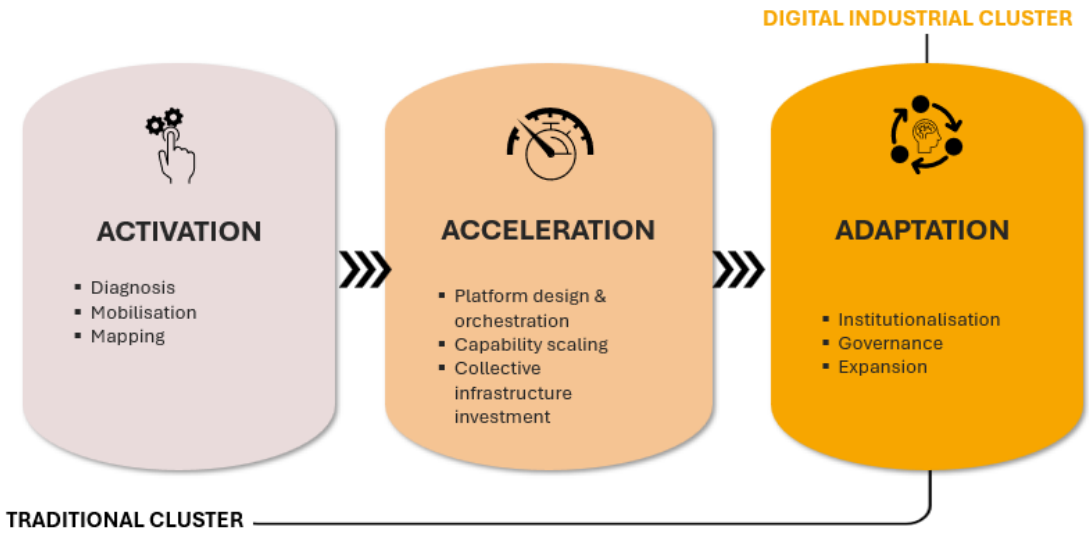


**Figure 6.** DICAAAP staged pathway illustrating coordination mechanisms required for progression toward Digital Industrial Cluster formation (Author's elaboration based on cluster evolution literature).

Figure 6 provides a visual overview of the DICAAAP pathway, illustrating how digital cluster transformation unfolds through successive yet interconnected stages that progressively reconfigure coordination, governance, and renewal capacity.

To link diagnosis with intervention, this study integrates life cycle indicators from Ostapenko et al. (2022) with empirically identified renewal drivers from König and Brenner

(2025). Together, these perspectives translate observable cluster conditions into staged implications for action, enabling DICAAAP to function as both an analytical and intervention-oriented framework.

Table 3 synthesises this integration by linking cluster characteristics and renewal mechanisms to the three DICAAAP stages. The Digital Industrial Cluster (DIC) is not included as a diagnostic category, as it represents the transformation outcome rather than an observed condition; instead, the table captures the pre-transformation indicators that DICAAAP seeks to reconfigure toward a DIC state.

**Table 3.** Integrated diagnostic framework linking cluster life cycle indicators, renewal mechanisms, and staged DICAAAP implications

(adapted and synthesised from Ostapenko et al., 2022; König & Brenner, 2025)

| Dimension | Lifecycle indicator (Ostapenko et al., 2022) | Interpretation (König & Brenner, 2025) | Implication for DICAAAP |
|---|---|---|---|
| **Cluster identity** | Precisely defined, narrow core business (maturity) | Cognitive lock-in often associated with decline | Need to reframe cluster narrative toward digital renewal |
| **Number of firms** | Stabilisation or decline | Low firm formation frequently associated with stagnation | Activation should stimulate experimentation and new entry |
| **Employment** | Stabilisation or decrease | Not decisive alone; reflects deeper processes | Use as warning signal, not sole diagnosis |
| **Network structure** | Dense but closed networks | Weak interaction → decline<br>strong interaction → renewal | Diagnose coordination failures; open networks digitally |
| **Innovation pattern** | Incremental or declining innovation | High innovation & new firm formation associated with renewal | Reposition digitalisation as renewal mechanism |
| **Universities & research** | Peripheral or weakly integrated | Strong renewal enabler | Mobilise universities as activation anchors |
| **External markets** | Saturation or declining exports | Competitive pressure without renewal often leads to decline | Use digital platforms to extend market reach |
| **Specialisation** | Strong path-dependent specialisation | Often associated with decline unless combined with diversification | Identify related digital diversification paths |
| **Policy interaction** | Passive or fragmented | Active interaction supports renewal | Activate public–private coordination |

While Table 3 establishes the diagnostic foundations of the DICAAAP framework by identifying life cycle conditions, renewal pressures, and coordination challenges, it does not yet explain how these conditions shape cluster trajectories over time. To address this, Figure 7 situates the DICAAAP stages within broader cluster transformation trajectories, illustrating how coordinated digital activation, acceleration, and adaptation can redirect mature clusters facing stagnation or decline toward renewal.

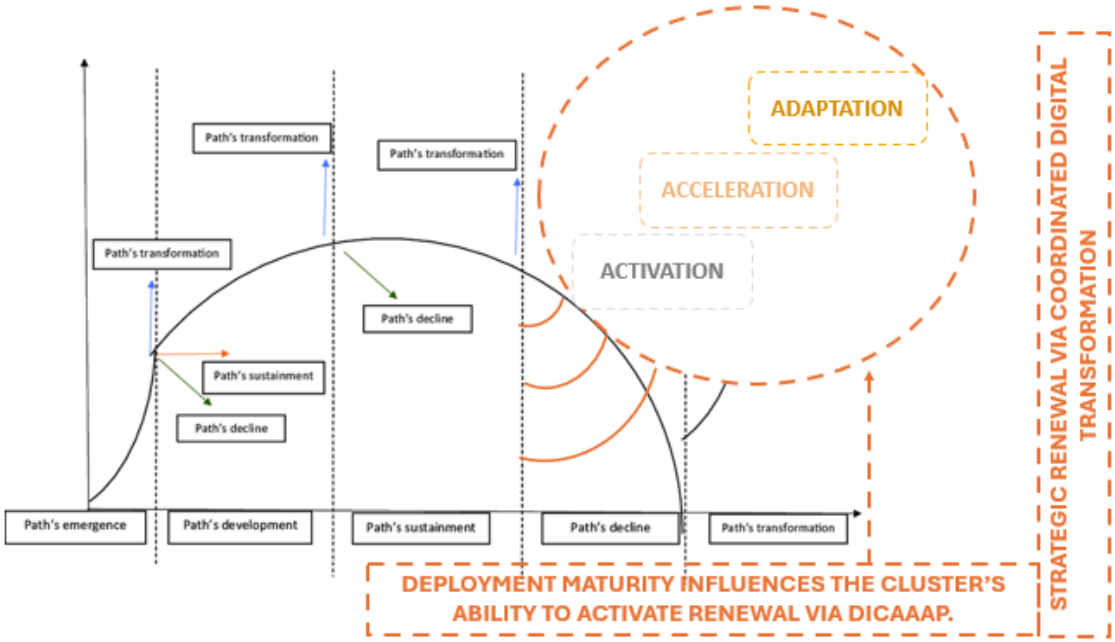


**Figure 7.** Positioning the DICAAAP framework within cluster life cycle and transformation trajectories (adapted from Ostapenko et al., 2022).

Building on this trajectory-level synthesis, Table 4 presents the DICAAAP pathway in a structured form by outlining, for each stage, the associated objective, governance logic, typical failure risks, and indicative indicators.

**Table 4.** DICAAAP staged pathway: Objectives, diagnostics, risks, and success indicators

Synthesizes Table 3 life cycle diagnostics with stage-specific interventions

| Stage | Core Objective | Analytical Focus | Governance Logic | Typical Failure Risk | Key Indicators |
|---|---|---|---|---|---|
| **Activation** | Establish digital transformation as a shared renewal challenge. | Diagnose life cycle position, renewal pressures, digital readiness, and coordination gaps. | Sense-making and justification of renewal; agenda-setting | ▪ Symbolic digitalisation<br>▪ Fragmented pilot initiatives<br>▪ Absence of a shared strategy | ▪ Shared diagnosis<br>▪ Explicit renewal narrative<br>▪ Aligned digital priorities.<br>▪ Identified coordination gaps |
| **Acceleration** | Translate renewal intent into scaled collective action. | Design and scale value-creating platforms, shared digital services, and collective capabilities. | Coordination and orchestration through rules for participation, data sharing, and interoperability | ▪ Failure to translate renewal intent into implemented initiatives.<br>▪ Limited participation of SMEs and peripheral actors<br>▪ Lack of integrated digital infrastructures | ▪ Shared digital initiatives in operation.<br>▪ Multi-actor participation<br>▪ Visible collective benefits |
| **Adaptation** | Institutionalise digital coordination for long-term renewal. | Integrate platforms, rules, and learning mechanisms into governance and strategy. | Formalisation, accountability, and continuous adjustment | ▪ Loss of momentum after funding ends<br>▪ Weakening of governance arrangements<br>▪ Dominance of narrow interests | ▪ Stable governance arrangements<br>▪ Digital KPIs integrated into strategy<br>▪ Sustained multi-actor participation.<br>▪ Capacity to extend coordination across regions |

Table 4 synthesises the DICAAAP pathway by explicitly linking diagnostic focus to governance logic, typical failure risks, and expected outputs across stages, thereby clarifying how digital cluster renewal is mobilised, scaled, and stabilised over time.

Building on this staged and diagnostic foundation, the following subsections operationalise DICAAAP by examining Activation, Acceleration, and Adaptation as sequential yet recursive mechanisms of cluster-level digital transformation.

### 3.3.1 Activation: diagnosing and mobilising digital renewal

Activation defines the entry point of the DICAAAP pathway. Its role is to establish digital transformation as a shared renewal challenge at the cluster level, rather than as a collection of isolated or firm-specific initiatives. In mature industrial clusters, digitalisation is often discussed in abstract terms without a common understanding of life cycle-related pressures or coordination failures. Activation addresses this gap by creating the conditions for collective sense-making and agenda-setting.

Through structured diagnosis, Activation clarifies the cluster's life cycle position, renewal pressures, digital readiness, and key coordination gaps. By doing so, it reframes dispersed digital activities as manifestations of a broader structural challenge, thereby legitimising the need for coordinated renewal. Activation does not aim to implement digital solutions; its function is to align actors around a shared problem definition that enables subsequent collective action.

### 3.3.2 Acceleration: scaling digital adoption and collective action

Acceleration represents the transition from mobilisation to collective action within the DICAAAP pathway. Once digital renewal is recognised as a shared objective, this stage focuses on translating intent into implemented cluster-level digital initiatives that generate collective value.

The role of Acceleration is to enable coordinated scaling through the development of shared digital services, platforms, and collective capabilities. At this stage, governance becomes increasingly important because informal coordination is no longer sufficient to support broad participation and integration. Acceleration therefore centres on coordination and orchestration mechanisms, such as rules for participation, data sharing, and interoperability, that allow digital initiatives to move beyond intent and isolated experimentation toward collective implementation.

### 3.3.3 Adaptation: institutionalising digital coordination and renewal

Adaptation constitutes the consolidation stage of the DICAAAP pathway. Its role is to ensure that digital coordination becomes durable rather than project-based or temporary. At this stage, the central challenge is not adoption or scale, but continuity over time.

Adaptation focuses on integrating digital platforms, coordination rules, and learning mechanisms into cluster governance and strategic routines. Through formalisation, accountability, and continuous adjustment, digital coordination is stabilised as a normal mode of cluster operation. From a life cycle perspective, Adaptation is critical for preventing loss of momentum once initial transformation efforts mature and for ensuring that digital transformation functions as a sustained path-renewal mechanism rather than a time-bound intervention.

## 3.4 Scope, assumptions, and applicability of the DICAAAP framework

DICAAAP is a governance-centred analytical framework designed to explain and structure digital renewal in mature industrial clusters. It targets ecosystems characterised by established coordination routines, institutional embeddedness, and emerging risks of stagnation or lock-in.

The framework is not intended to explain early-stage cluster emergence or purely entrepreneurial digital ecosystems. Instead, it focuses specifically on mature clusters in which digital transformation requires collective coordination rather than isolated firm-level optimisation.

DICAAAP assumes that digital transformation introduces interdependencies, such as shared data infrastructures, interoperability requirements, and cross-regional collaboration, that cannot be effectively governed by individual firms alone. Its analytical contribution lies in specifying when and why governance becomes critical across the Activation, Acceleration, and Adaptation stages.

The framework is process-oriented rather than deterministic. Stage progression is neither automatic nor linear; clusters may remain partially transformed if governance conditions are not consolidated. In this thesis, DICAAAP functions as an analytical lens for diagnosing the position of Energy Vaasa within a staged digital renewal pathway. Empirical analysis may also reveal preparatory governance conditions that precede Activation, particularly where clusters lack shared diagnostics or strategic alignment.

# 4 Research methodology

This chapter outlines the methodological design and reasoning underpinning the study, structured using Saunders et al.'s (2007) research onion as a guiding framework. The research onion provides a layered model for organising methodological choices, ranging from philosophical assumptions to research approach, strategy, and methods. In this study, it is used to ensure coherence between the research aim, theoretical framing, and empirical procedures, rather than as a prescriptive template.

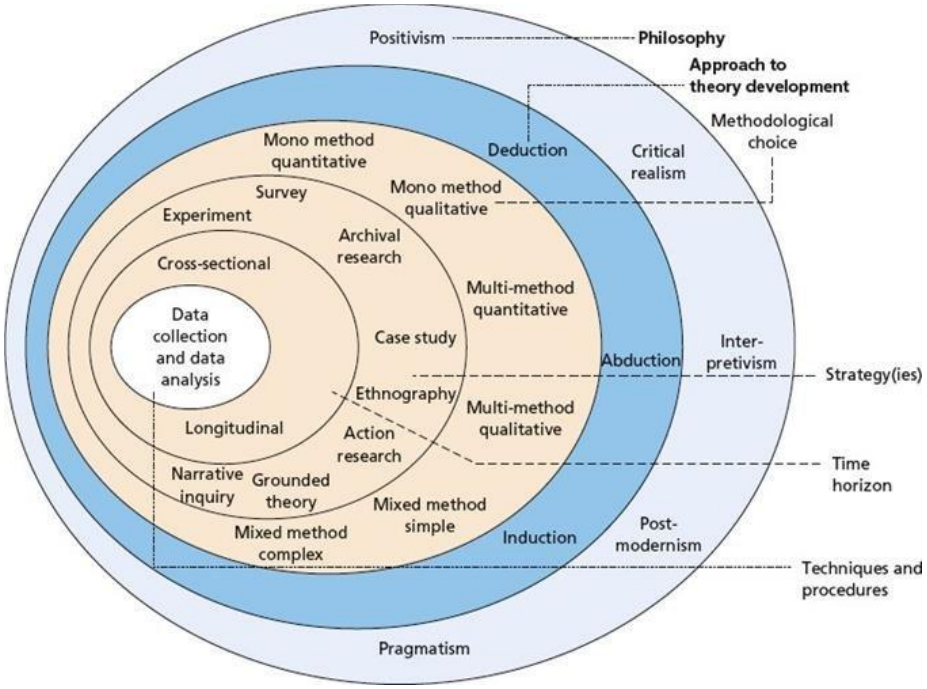


**Figure 8. Saunders et al.'s (2007) research onion illustrating philosophical, methodological, and procedural choices**

In this study, the research onion serves as a structuring device for explaining how methodological decisions support the examination of the DICAAAP framework, derived from the Digital Industrial Cluster (DIC) concept, as a strategic mechanism for renewal and cross-regional scaling in mature industrial clusters. It helps clarify the alignment between the study's interpretivist–critical realist philosophical stance, qualitative orientation, single-case study strategy, and theory-building objectives.

The study follows an abductive research logic, characterised by iterative movement between theoretical framing and empirical material. Existing literature on cluster life cycle dynamics, digital transformation, and digital agglomeration informed the initial conceptual framing, while empirical insights from the Energy Vaasa case continuously refined and adjusted this framing.

## 4.1 Research design overview

This study adopts a qualitative, abductive, and emergent research design to examine how the DICAAAP framework, derived from the Digital Industrial Cluster (DIC) concept, can be operationalised as a strategic mechanism for renewal and cross-regional scaling in mature industrial clusters. Given the conceptual novelty and limited empirical grounding of the DIC concept and its operationalisation through DICAAAP, a flexible design was required to support iterative movement between theoretical framing and empirical insights.

The research is structured as a single-case study centred on the Energy Vaasa cluster, which serves as an empirical context for investigating digitally enabled cluster renewal in practice. In this thesis, cluster refers to the geographically anchored industrial agglomeration, while ecosystem is used to denote the broader set of interdependent actors and institutional arrangements involved in coordination and renewal. This design enables in-depth exploration of both the organisational setting and the conceptual framework under development, supporting theory refinement through sustained engagement with empirical material rather than hypothesis testing (Yin, 2018).

The primary objective of the research is to develop and refine the DICAAAP framework, translating the abstract logic of the DIC model into a structured and analytically usable pathway. In line with the principle of methodological fit, qualitative methods were employed to generate context-sensitive insights appropriate for an under-theorised research domain (Edmondson & McManus, 2007).

Specifically, the analysis examines both cluster context (Energy Vaasa's coordination practices and governance dynamics) and conceptual construct (DICAAAP stage logic and renewal mechanisms) in parallel. This dual focus grounds the DICAAAP framework in observed practices while contributing to theory development (Eisenhardt, 1989).

## 4.2 Research philosophy

Every research design is grounded in a guiding philosophical orientation, which shapes the assumptions about reality (ontology), knowledge (epistemology), and how knowledge can be obtained (Saunders et al., 2019, 2023). This study investigates how emerging digital tools and collaborative platforms can support the transformative renewal of mature industrial clusters, with a specific focus on the Energy Vaasa ecosystem. Given the layered institutional and organisational nature of industrial clusters, the research adopts a combined interpretivist–critical realist stance (Saunders et al., 2023).

Interpretivism emphasises the importance of understanding how actors such as managers, policymakers, and cluster facilitators assign meaning to digital transformation processes. It seeks to capture subjective interpretations, individual experiences, and the context-bound logics that shape strategic and organisational decisions within clusters.

However, interpretivism alone may overlook the structural and systemic conditions that constrain or enable those interpretations. To address this, the study incorporates critical realism, which acknowledges that human perceptions are embedded and influenced by underlying mechanisms, such as institutional structures, inter-organisational power dynamics, and technological infrastructures (Uren & Edwards, 2023).

Digital transformation is frequently reduced to technological adoption, while renewal processes are shaped by deeper institutional and organisational conditions (Vinsel & Russell, 2020). Combining interpretivism and critical realism allows this study to examine both actors' meaning-making and the structural mechanisms shaping digital cluster renewal.

This philosophical orientation provides a coherent foundation for employing qualitative, exploratory methods, particularly semi-structured interviews. These methods are well-suited to uncovering both subjective stakeholder experiences and the structural dynamics that influence them (Eriksson & Kovalainen, 2016).

## 4.3 Research approach, strategy, and process

The research process involved iterative movement between empirical material and theoretical interpretation. Cluster life cycle theory and the Digital Industrial Cluster (DIC) model are treated as sensitising concepts rather than fixed analytical frames. As empirical engagement progressed, observations from the field generated analytical tensions and 'surprises' that prompted theoretical refinement throughout the research process (Dubois & Gadde, 2002).

The research is structured as a single-case study, with the Energy Vaasa cluster serving as the focal case. Energy Vaasa represents a theoretically informative case because its strong industrial maturity and institutional legitimacy coexist with unresolved challenges in digitally mediated collaboration and governance. The single-case approach supports analytical generalisation by allowing theoretical insights to be developed through close engagement with empirical material rather than through statistical inference (Yin, 2018).

Within the case, three embedded stakeholder domains were examined to capture the layered structure of the cluster ecosystem:

(1) cluster management and facilitation actors (e.g., Technology Centre Merinova),
(2) industrial firms, and
(3) institutional partners such as policy bodies.

In addition to core case actors, selected external informants from other Finnish and European clusters, as well as EU-level policy organisations, were included as analytical extensions rather than separate cases. Their role was to provide contextual contrast and support triangulation by situating the Energy Vaasa findings within broader European

cluster development discussions. This approach strengthened theoretical insight while maintaining single-case coherence. The iterative research process guiding framework development is illustrated in Figure 9.

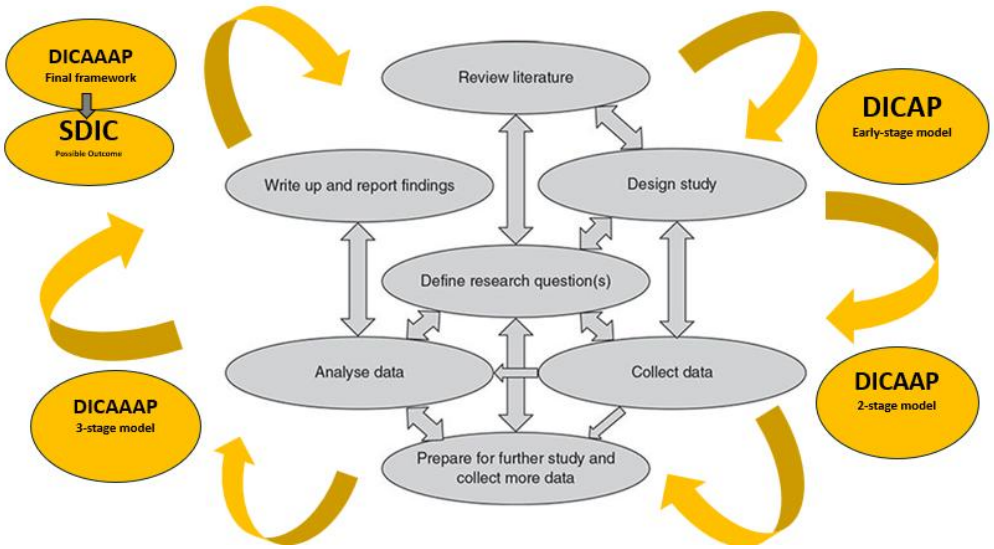


**Figure 9.** Emergent and abductive research process guiding framework development, adapted from Lee and Saunders (2017)

Figure 9 illustrates the emergent research process through which the DICAAAP framework was developed. The study initially engaged with the Digital Industrial Cluster concept through an early-stage DICAP model derived from the literature. As empirical engagement with the Energy Vaasa case progressed, iterative cycles of data collection and analysis revealed limitations in the initial framework, particularly with respect to long-term governance continuity, institutionalisation, and cross-regional sustainability. These empirical insights motivated the extension of the framework beyond activation and acceleration to include an explicit adaptation phase, resulting in the DICAAAP framework. This evolution reflects a shift from examining deployment feasibility toward analysing the governance and coordination conditions that shape progression across DICAAAP stages.

To ensure qualitative rigour, the study was guided by Tracy's (2010) Big-Tent criteria, with particular emphasis on credibility, coherence, reflexivity, and meaningful contribution.

Credibility was supported through triangulation across stakeholder groups and data sources. Coherence was ensured through strong alignment between the research design, analytical process, and outcomes. Reflexivity was maintained through transparent documentation of analytical decisions throughout the research process. Finally, the study's contribution is demonstrated through the development of an empirically grounded and analytically usable framework for digitally enabled cluster renewal.

## 4.4 Data collection and analysis

This study employed a qualitative research design that combined semi-structured interviews with contextual secondary data to investigate digital transformation, collaborative dynamics, and the operational feasibility of the DICAAAP framework within the Energy Vaasa ecosystem and its extended network.

Data collection was guided by the DICAAAP framework, which informed the formulation of stage-specific guiding questions corresponding to Activation, Acceleration, and Adaptation. These guiding questions were designed to prompt reflection on renewal pressures, coordination challenges, governance arrangements, and the durability of digital initiatives at the cluster level. Rather than functioning as a fixed questionnaire, they served as flexible analytical prompts, allowing interview focus to evolve in response to participants' experiences and interpretations.

### 4.4.1 Primary data: semi-structured interviews

Primary data were collected through 12 semi-structured interviews with key stakeholders across the Energy Vaasa ecosystem and related national and European cluster networks. The interviews were conducted between June 2025 and January 2026, with an average duration of approximately 20–60 minutes. Interviewees represented a diverse set of actors, including firm representatives, cluster management and facilitation actors (Technology Centre Merinova), regional policymakers, university-affiliated project managers, and representatives of other Finnish and European cluster organisations.

The interviews explored participants' perceptions of digital transformation, inter-organisational collaboration, and governance arrangements in relation to the DICAAAP framework. A semi-structured interview format was chosen to balance analytical consistency with flexibility, allowing participants to elaborate on context-specific experiences while ensuring systematic coverage of themes relevant to the research aim. The interview guide reflected the three DICAAAP stages (Activation, Acceleration, and Adaptation) and is provided in Appendix 1.

Interviews were conducted either in person, online, or via written responses depending on participant availability and preference. Interviews were conducted primarily in English, which served as the common working language among participants. Where consent was granted, interviews were audio-recorded and transcribed verbatim to support analytical rigour.

### 4.4.2 Secondary data

Secondary data were used selectively to contextualise and support the interpretation of interview findings rather than as an independent object of analysis. These sources included policy documents, regional and national strategy reports, cluster development materials, and European-level innovation and digitalisation documents relevant to energy transition and cluster governance.

The use of secondary data supported contextual triangulation by situating interview insights within the broader institutional and policy environment in which Energy Vaasa operates, thereby strengthening interpretive depth and analytical credibility (Flick, 2018).

### 4.4.3 Sampling strategy

A purposive sampling strategy was adopted, appropriate for qualitative research focused on complex, context-dependent phenomena (Saunders et al., 2023). Participants were

selected based on their organisational roles, sectoral expertise, and direct involvement in innovation, digital transformation, or collaborative activities within or closely connected to the Energy Vaasa ecosystem.

The final sample was organised across five stakeholder categories:

(1) cluster governance and facilitation actors,

(2) regional policy representatives,

(3) private sector actors inside and outside the cluster, representing diverse firm sizes,

(4) EU-level policy actor, and

(5) external cluster representatives from Finland and Europe.

External actors were included as contextual informants rather than separate cases, providing comparative perspectives relevant to cross-regional collaboration and cluster renewal while preserving the coherence of the single-case design. Sampling was concluded once thematic saturation was reached, meaning that additional interviews were unlikely to generate substantively new insights for the operationalisation of the DIC concept through DICAAAP or the refinement of the DICAAAP framework.

Table 5 provides an overview of the interview sample and illustrates the distribution of interviewees across stakeholder categories.

**Table 5.** Interview sample overview (N = 12)

| Interviewee Category | Cluster Position | Role | Code(s) | N |
|---|---|---|---|---|
| Merinova | Inside | Management team | MTI0, MTI2, MTI4 | 3 |
| Small company | Inside | Co-founder / CEO | SCI11 | 1 |
| Large company | Inside | Director | LCI5 | 1 |
| University (dual role at Merinova) | Inside | Management team | UMTI3 | 1 |
| Regional policy official | Inside | Strategy and development | RPI7 | 1 |
| European Commission | Outside | Policy officer | EPI1 | 1 |
| Medium-sized company | Outside | Co-founder / CBDO | MCOI6 | 1 |
| National cluster representative | Outside | RDI specialist | NCI8 | 1 |
| European association of clusters | Outside | President | EACI9 | 1 |
| European energy cluster | Outside | Representative | ECI10 | 1 |

**Note:** Interview codes LCI5 and UMTI3 reflect dual institutional roles (firm/university and cluster organisation). MCOI6 represents a dual informant role as both a firm representative and digital platform provider. The regional policy representative is treated as part of the cluster due to institutional embeddedness in Energy Vaasa's governance and smart specialisation strategy.

### 4.4.4 Data analysis

Interview data were analysed using reflexive thematic analysis, guided by Braun and Clarke's (2006) six-phase framework: familiarisation with the data, initial coding, theme development, theme review, theme definition, and reporting. This approach supports systematic theme development while remaining sensitive to participants' language and contextual meanings (Braun & Clarke, 2006).

Initial coding was informed by sensitising concepts from the Activation, Acceleration, and Adaptation stages of the DICAAAP framework, while remaining open to inductively emerging themes. Illustrative indicators and analytical prompts used during coding are

provided in Appendix 2, while a broader diagnostic and intervention menu is presented separately in Appendix 3 for transparency.

The analytical process was iterative and reflexive, consistent with the study's interpretivist–critical realist positioning. To enhance transparency and analytical rigour, reflexive journaling, theme mapping, and systematic documentation of interpretive decisions were employed throughout the analysis process (Ahmed et al., 2025). Coding and theme development were conducted manually through iterative reading of interview transcripts and the construction of structured coding tables, allowing emerging themes to be compared across interviews and stakeholder groups. The staged structure of DICAAAP was iteratively refined through engagement with the empirical material, allowing observed coordination gaps and governance tensions to inform stage boundaries and diagnostic emphasis.

This iterative refinement ensured that the framework remained directly aligned with the study's main research question, which seeks to understand how the DIC concept can be operationalised through the DICAAAP framework as a strategic tool for renewal and cross-regional scaling in mature clusters.

### 4.4.5 Data protection and ethics

This study adhered to the ethical standards of the University of Vaasa and complied with the EU General Data Protection Regulation (GDPR) and the Finnish Data Protection Act. Participation was voluntary, and all participants received a Participant Information Sheet and an informed Consent Form prior to data collection.

Informed consent was obtained before each interview, including explicit consent for audio recording where applicable. Participants were informed of their right to withdraw from the study at any stage without negative consequences. All interview data were anonymised during transcription, and identifying information was removed or replaced with interview codes to ensure confidentiality.

Digital research data were stored on password-protected university servers, while any physical materials were securely stored with access restricted to the researcher and academic supervisor. Research data will be retained for a maximum of five years following completion of the study and will then be securely destroyed in accordance with institutional guidelines. Ethical procedures were discussed with the thesis supervisor, and relevant documentation is provided in Appendix 5.

This methodological design establishes coherence between empirical findings, analytical positioning, and the staged framework developed in Chapters 5–7.

# 5 Empirical findings

This chapter presents the empirical findings from twelve semi-structured interviews conducted with cluster managers, firm representatives, policy actors, and external experts (Table 5). The findings are organised around the Activation, Acceleration, and Adaptation stages of the DICAAAP framework. In the empirical analysis, these stages function as sensitising concepts guiding analytical attention rather than as predetermined categories.

The chapter reports recurring perceptions and practices across actor groups. It focuses on how respondents describe the current functioning of the Energy Vaasa cluster, particularly regarding renewal, digital coordination, and collaboration practices. The findings presented here reflect patterns that appeared consistently across multiple interviews and actor groups rather than isolated individual views. Causal explanations and theoretical interpretation are developed in Chapter 6.

To maintain readability, only selected quotations are presented in this chapter. The full coded quotation set is provided in the appendices. Appendix 5.0 contains contextual quotations describing the cluster management mandate, while Appendices 5.1–5.3 present stage-specific illustrative quotations supporting the findings reported here.

Cluster management actors described Technology Centre Merinova as a trusted intermediary responsible for facilitating networking, project formation, and interaction between firms, universities, and public authorities. Respondents characterised this role as combining strategic coordination with operational responsibilities. At the same time, interviewees most frequently emphasised networking, facilitation, and project execution, while less frequently describing routines for systematic steering of long-term digital renewal (see Appendix 5.0 for additional contextual quotations).

One cluster management respondent summarised this dual role as follows:

> *"Strategically, we coordinate the cluster's direction, strengthen RDI collaboration, and align our work with regional and national clean transition goals. Operationally, we connect members, facilitate joint projects, and promote collaboration …."* (MTI2)

Respondents also distinguished between digital visibility and digital coordination. While Energy Vaasa maintains an online presence and participates in digital portals, interviewees did not describe digital tools as integral to cluster governance or collective decision-making processes.

Overall, the findings suggest strong institutional embeddedness alongside limited integration of digital coordination mechanisms at cluster level. The staged findings that follow are presented to clarify patterns across actor groups. Additional quotations are provided in the appendices, while analytical interpretation is developed in Chapter 6.

## 5.1 Activation: fragmented life cycle assessment and diagnostic gaps

Interviewees consistently described Energy Vaasa as a mature and well-established industrial cluster. At the same time, respondents expressed different views regarding the cluster's current life-cycle position. These assessments varied across actor groups and were expressed in the absence of shared diagnostic reference points. While most respondents recognised the need for continued development or renewal, their interpretations differed systematically according to organisational role. Appendix 5.1 summarises differences in how life-cycle information is described and monitored across actor groups.

Within the cluster management team, respondents generally described Energy Vaasa as stable and well developed. One interviewee referred to quantitative indicators such as the number of firms and total turnover but also expressed uncertainty regarding how these indicators are currently monitored in practice:

> *"The number of companies is one indicator. Also, the total turnover of companies. I don't know how these are monitored at the moment."* (MTI0)

Other management respondents emphasised relational cohesion and collaboration as indicators of the cluster's development stage. In these accounts, maturity was associated primarily with established ways of working and strong inter-firm relationships rather than with formal assessment criteria.

A different perspective emerged from a boundary actor with a dual management and academic role. This respondent described the cluster as maintaining its current position while awaiting external developments, particularly the green transition to stimulate renewed growth:

> *"I would describe it as sustaining and waiting for the green transition to trigger growth again."* (UMTI3)

Firm-level perspectives revealed further variation. A representative of a large firm described Energy Vaasa as highly mature, emphasising well-established collaboration practices while acknowledging the need to identify new growth opportunities to avoid stagnation. In contrast, an SME respondent expressed a more cautious view, referring to limited novelty in recent collaborations:

> *"There may be some stagnation."* (SCI11)

Across interviews, respondents consistently recognised cluster maturity. However, no interviewee referred to shared diagnostics, formal monitoring practices, or collectively agreed reference points for assessing the cluster's life-cycle position. Assessments therefore remained role-dependent and individually interpreted rather than collectively aligned. This absence of shared diagnostic practices forms an important empirical context for the Acceleration-related dynamics discussed in the next section.

## 5.2 Acceleration: digital ambition without infrastructure

Interviewees frequently referred to ambitions associated with Acceleration, particularly digital coordination, cross-regional collaboration, and the scaling of joint activities. However, these ambitions were not accompanied by shared digital infrastructure, clear facilitation arrangements, or established coordination mechanisms. As in the Activation stage, perspectives varied systematically by actor position.

Cluster management accounts described Acceleration primarily in strategic and forward-looking terms. One respondent highlighted the development of an AI-assisted digital platform intended to support partner discovery, knowledge sharing, and collaboration among cluster members:

> "*We are the first cluster in Finland to develop an AI-assisted digital platform… The platform will help our members connect more effectively, share knowledge, and identify new opportunities for cooperation.*" (MTI2)

At the same time, other management respondents noted the absence of an operational cluster-level digital system. While large firms were described as using advanced digital tools internally, similar systems were not perceived to exist at the collective cluster level:

> *"Large corporations have internal digital platforms and use digital tools internally, but for the cluster as a whole, there is no such platform."* (MTI4)

A boundary actor further noted that although the cluster maintains digital visibility through websites and portals, digital tools currently play only a limited role in cluster management and coordination activities.

Firm-level perspectives highlighted the practical implications of this situation. A large-firm respondent emphasised that digital systems developed internally by major companies cannot easily be extended to smaller suppliers and therefore should not be imposed at cluster level. In contrast, an SME respondent expressed clear functional demand for cluster-wide digital coordination mechanisms, particularly for partner search and cross-regional collaboration:

> *"More networking with other companies. Partner search and project matchmaking are the most important."* (SCI11)

Additional interview excerpts illustrating variation in acceleration-related perspectives are provided in Appendix 5.2. Overall, the findings indicate that ambitions related to digital scaling are widely articulated across the cluster. However, shared infrastructure, transparency mechanisms, and facilitation capacity remain limited. Digital coordination is therefore described primarily as a future enabler rather than as an embedded cluster-level practice.

## 5.3 Adaptation: trust-based coordination and limited institutionalisation

Interview data indicate that Energy Vaasa has not yet entered a fully institutionalised Adaptation phase. While respondents recognised emerging digital and cross-regional ambitions, they did not describe stable governance arrangements, shared rules, or formalised practices capable of sustaining digital coordination over time. Instead, adaptation-related dynamics were portrayed as conditional and largely reliant on trust-based and informal coordination.

Across actor groups, interviewees consistently emphasised personal relationships, familiarity, and repeated interaction as the primary foundations of collaboration. Trust was described as a prerequisite for cooperation, particularly when coordination extends beyond existing networks or regional boundaries:

> *"People are still people. Trust is the key at the beginning. Digital platforms can feel 'not real,' so you need trust-building first."* (MTI4)

A regional policy informant similarly emphasised that coordination often relies on trust-based collaboration rather than formal governance arrangements (see Appendix 5.3).

At the same time, respondents did not describe widely shared or binding rules governing digital platforms, data sharing, or long-term coordination practices. References to principles such as transparency or neutrality were framed as general intentions rather than as established governance routines:

> *"We apply the same principles to our digital systems as to our cluster management, but clear rules need to be agreed early on."* (MTI2)

Firm-level and boundary perspectives further highlighted uncertainty regarding coordination responsibility and organisational form. A large-firm respondent stressed that cluster-level digital initiatives should not be led by a dominant firm, emphasising the need for neutral intermediaries to ensure inclusiveness. A respondent with a dual management–academic role further questioned whether geographically bounded cluster arrangements remain appropriate as digital and cross-regional coordination intensifies:

> *"If the cluster becomes more digital, it will automatically expand its geographical presence… it may no longer be appropriate to call it a 'cluster'."* (UMTI3)

Taken together, these accounts suggest that coordination within Energy Vaasa continues to rely primarily on trust-based practices and project-level arrangements, while formal governance structures remain limited. A fuller set of interview quotations related to adaptation and governance practices is presented in Appendix 5.3.

Across Sections 5.1–5.3, the findings highlight three recurring patterns:

1. role-dependent life-cycle assessment without shared diagnostics,
2. digital ambition without shared cluster-level infrastructure in use, and
3. reliance on trust-based coordination without formalised digital governance routines.

These patterns form the empirical foundation for the analytical interpretation developed in Chapter 6.

# 6 Analysis and revised DICAAAP framework

This chapter interprets the empirical findings presented in Chapter 5 through the analytical lens of the DICAAAP framework. Rather than repeating interview accounts, the focus here is on explaining how the observed patterns influence cluster-level coordination dynamics. The chapter therefore moves from descriptive reporting toward analytical interpretation.

The analysis shows that Energy Vaasa does not fit neatly within a single stage of the DICAAAP transformation pathway. Instead, the cluster occupies an intermediate position characterised by fragmented Activation, limited Acceleration, and pre-adaptive coordination. These conditions are interconnected, as weaknesses at one stage influence the possibilities available at the next.

Across the empirical material, three recurring patterns emerge. First, actors recognise that the cluster has reached maturity and faces pressures for renewal, yet this awareness is not translated into shared diagnostic practices. Second, digital ambitions are widely articulated but remain weakly embedded in collective coordination structures. Third, collaboration remains active and stable but is sustained mainly through trust-based and project-level interaction rather than institutionalised governance arrangements.

Together, these patterns suggest that the main constraint is not the absence of digital ambition or firm-level capability, but the incomplete development of cluster-level coordination mechanisms.

## 6.1 Fragmented Activation: life cycle awareness without diagnostic alignment

The findings indicate that Energy Vaasa has only partially entered the Activation stage. Actors across the cluster recognise its maturity and acknowledge the need for renewal. However, this awareness remains dispersed across actor groups rather than

consolidated into a shared understanding of the cluster's position or future direction. Renewal is recognised, but it is not yet framed through common diagnostic reference points capable of guiding coordinated action.

A central feature of this condition is the gap between recognition and alignment. Cluster management respondents generally describe Energy Vaasa as stable, mature, and well-functioning. Their assessments emphasise continuity, strong relationships, and established collaboration. While these observations highlight the institutional strength of the cluster, they are not supported by clearly defined monitoring routines, shared indicators, or commonly agreed evaluation criteria. As a result, positive assessments of the cluster coexist with uncertainty regarding how its development is currently assessed.

Actors therefore recognise maturity but do not operationalise it collectively. Indicators such as firm numbers, turnover, employment levels, and cluster membership are occasionally mentioned in interviews, yet they do not form part of a systematic monitoring framework. These indicators function more as informal reference points than as instruments for governance or strategic coordination. In this sense, the case illustrates lifecycle awareness without a shared diagnostic system capable of supporting collective interpretation.

Narrative framing further reinforces this condition. Cluster management accounts frequently highlight stability, continuity, and long-standing cooperation within the ecosystem. These narratives strengthen confidence in the cluster's institutional foundations, but they also reduce the urgency of renewal as a collective coordination challenge. The issue is not that actors deny the need for development; rather, renewal tends to be framed cautiously in ways that preserve continuity rather than mobilise coordinated change.

Boundary perspectives reinforce this interpretation. Several respondents associate future renewal primarily with external developments, particularly the green transition in

the energy sector. In these accounts, change is expected to emerge from shifts in the broader industrial environment rather than from internally driven coordination reforms. This perspective reduces pressure to establish shared diagnostics, as renewal becomes associated with external opportunity rather than organisational preparedness.

Firm-level perspectives reveal a similar pattern from another angle. Representatives of large firms describe Energy Vaasa as mature and collaborative while acknowledging the need for new growth paths. Smaller firms are more likely to point directly to stagnation risks and limited novelty in recent collaborations. These views do not contradict one another but remain tied to the specific positions of different actors. They are not integrated into a shared interpretation of the cluster's current trajectory.

External informants with experience in cluster governance similarly emphasised that effective renewal processes typically rely on shared diagnostic routines and clearly defined monitoring indicators (EACI9; NCI8). Their observations reinforce the interpretation that, in the Energy Vaasa case, life-cycle awareness exists but has not yet consolidated into a shared diagnostic framework.

Importantly, external informants did not identify a lack of technological capability within the cluster. Instead, they pointed to the absence of shared diagnostic and coordination infrastructure. This distinction is analytically significant because it shows that the main constraint lies not in recognising renewal pressures, but in the absence of mechanisms that translate recognition into collective diagnosis and coordinated action.

Overall, the evidence indicates that Energy Vaasa exhibits life-cycle awareness without diagnostic alignment. Activation is therefore present but incomplete. Actors recognise maturity and the need for renewal, yet they do not share an agreed basis for assessing the cluster's position, defining renewal priorities, or translating awareness into collective agenda-setting. This fragmented Activation becomes particularly consequential in

the next stage, where ambitions for scaling digital coordination emerge without a shared diagnostic foundation. A structured synthesis linking empirical patterns to their analytical interpretation and theoretical anchors is provided in Appendix 6.1.

## 6.2 Limited Acceleration: digital ambition without value anchoring

The analysis suggests that Energy Vaasa exhibits limited progression within the Acceleration stage. Across actor groups, respondents articulate strong ambitions related to digital coordination, AI-assisted collaboration, partner discovery, and cross-regional expansion. However, these ambitions have not yet consolidated into shared infrastructure, routine collective use, or stable coordination practices. Digitalisation therefore appears primarily as strategic intent rather than as operational cluster-level capacity embedded in everyday interaction.

The planned AI-assisted digital platform represents the most visible example of this dynamic. Interviewees describe the platform as a future mechanism for collaboration, knowledge exchange, and matchmaking among cluster members. The initiative signals a clear commitment to digital development. At the same time, respondents do not describe the platform as currently embedded in routine coordination or governance processes. In this sense, the platform represents ambition rather than fully realised acceleration.

This gap between intention and operational embedding appears throughout the data. Cluster management actors frequently speak about digitalisation, artificial intelligence, and cluster expansion in forward-looking terms. Yet respondents consistently emphasise that no cluster-wide digital system currently structures everyday interaction or decision-making. Existing digital tools are mainly used for communication, visibility, and information exchange rather than for collective coordination.

Actor position shapes how this situation is experienced. Large firms already operate advanced internal digital systems and therefore depend less on cluster-level coordination

infrastructure. Smaller firms, in contrast, express a clearer demand for shared digital tools that facilitate partner search, matchmaking, and collaboration beyond the region. As a result, digital capability exists at the firm level but does not translate into shared cluster-level infrastructure capable of producing collective benefits.

This unevenness points to a deeper issue: the cluster lacks a shared value logic that would make digital coordination meaningful across different actor groups. Respondents often describe what digital tools could enable but provide few examples of concrete cluster-level outcomes already generated through digital coordination. Without visible and widely recognised benefits, participation in digital initiatives remains tentative.

Additional coordination conditions reinforce this limitation. Interviewees mention limited transparency regarding cluster membership, unclear participation boundaries, and weak visibility of collaboration outcomes. These gaps reduce accountability and make it difficult for digital initiatives to accumulate coordination effects over time.

External actors with experience in digital platforms and cluster policy likewise emphasised that cluster-level digital coordination typically requires clear everyday value and active facilitation rather than the mere introduction of technological tools (EPI1; EACI9). Their observations highlight that the main limitation in the Energy Vaasa case lies not in digital ambition but in the absence of coordination mechanisms capable of embedding digital initiatives into routine cluster interaction.

Overall, the evidence suggests that Energy Vaasa exhibits digital ambition without collective anchoring. Acceleration is visible in strategic narratives, planned infrastructure, and interest in cross-regional collaboration. However, these ambitions remain weakly institutionalised because they are not supported by shared coordination routines, clear value propositions, or facilitation structures capable of sustaining participation. Appendix 6.2 summarises the governance gaps that constrain the consolidation of Acceleration at cluster level.

## 6.3 Pre-Adaptive coordination: trust, informality, and limits to institutionalisation

The findings further indicate that Energy Vaasa has not yet reached consolidated Adaptation. Instead, coordination remains pre-adaptive. Collaboration is active and stable, but it relies mainly on trust-based relationships, informal interaction, and project-level arrangements rather than institutionalised governance structures capable of supporting durable digital coordination.

Trust functions as a central coordination mechanism within the cluster. Interviewees repeatedly emphasise personal relationships, familiarity, and repeated interaction as the basis of collaboration. These trust-based relations facilitate cooperation within established networks and help reduce friction in project formation.

However, trust operates primarily as a stabilising mechanism rather than as a scalable governance arrangement. It works effectively when actors know each other and collaboration follows established patterns. Its effectiveness decreases when coordination expands beyond familiar networks, particularly in digitally mediated or cross-regional contexts where interpersonal relationships alone cannot sustain coordination.

This limitation becomes visible when examining digital and cross-regional ambitions. These ambitions require coordination mechanisms that extend beyond individual projects and informal interaction. Yet respondents do not describe stable governance arrangements capable of supporting this transition. Formal mandates for digital coordination, clearly defined participation rules, shared monitoring systems, and accountability structures remain largely absent.

Consequently, digital initiatives remain dependent on voluntary participation. While initiatives may generate temporary collaboration, they do not automatically become

embedded in cluster governance routines. Coordination therefore remains episodic rather than institutionalised.

Leadership questions further reinforce this pre-adaptive condition. Large-firm respondents emphasise that dominant firms should not lead cluster-level digital coordination due to differences in capabilities and concerns about neutrality. At the same time, no clearly defined actor is widely recognised as responsible for long-term orchestration. The result is a coordination gap in which actors recognise the need for facilitation but lack agreement on who should provide it.

External cluster representatives similarly emphasised that sustained digital collaboration typically requires explicit governance arrangements, stable orchestration roles, and long-term coordination capacity (EACI9; NCI8). Their observations support the interpretation that, although trust-based collaboration remains strong within Energy Vaasa, the absence of institutionalised governance structures limits the durability of digital transformation initiatives.

Collectively, these patterns indicate that Energy Vaasa is best understood as pre-adaptive. Collaboration remains strong but lacks the institutional consolidation required for durable digital coordination. A synthesis of the coordination characteristics underlying this pre-adaptive condition is presented in Appendix 6.3.

## 6.4 Revised DICAAAP framework and governance conditions

When the three analytical sections are considered together, the findings show that the limitations observed in the Energy Vaasa cluster are not isolated issues but part of a connected sequence of coordination challenges. In this thesis, the Digital Industrial Cluster (DIC) represents the target organisational configuration, while the DICAAAP framework describes the staged governance pathway through which mature clusters can move toward that outcome.

The empirical analysis demonstrates how weaknesses at one stage influence the conditions for the next. Fragmented Activation limits the cluster's ability to establish a shared diagnostic understanding of renewal pressures. Limited Acceleration shows that digital ambitions have not yet translated into visible collective value or stable coordination routines. Pre-adaptive coordination indicates that collaboration remains largely trust-based and project-oriented rather than embedded in governance structures capable of sustaining digital transformation over time.

Together, these dynamics clarify the empirical position of Energy Vaasa within the DICAAAP pathway. The cluster is not absent from transformation processes. Actors recognise maturity, express ambitions related to digitalisation and cross-regional collaboration and maintain active interaction across the ecosystem. However, the cluster remains positioned between stages because the governance conditions required for consolidation are only partially developed.

At the Activation stage, the central challenge is not whether actors recognise cluster maturity but whether this recognition is translated into shared diagnostic practices and monitoring routines. At the Acceleration stage, the key issue is not whether digital tools are envisioned but whether they are embedded in everyday cluster coordination and capable of generating visible collective value. At the Adaptation stage, the challenge concerns institutional durability. Collaboration remains active but depends primarily on interpersonal trust and project-based interaction rather than stable governance arrangements.

External perspectives from European cluster organisations and policy actors support this interpretation. These informants emphasised that successful digital cluster initiatives typically require clearly defined orchestration roles, shared digital infrastructures, and institutionalised governance arrangements capable of sustaining collaboration beyond individual projects (EACI9; EPI1). Supporting triangulation evidence from external informants is summarised in Appendix 6.4.

In comparison, the Energy Vaasa ecosystem demonstrates strong relational collaboration but lacks the formalised coordination structures necessary for durable digital transformation. This contrast further reinforces the conclusion that governance development, rather than technological availability alone, represents the critical condition for progression within the DICAAAP pathway.

These observations suggest that stage progression within DICAAAP depends on whether governance capacity is built and stabilised at each stage. In this study, these requirements are conceptualised as governance conditions. Each stage of the pathway stabilises only when specific coordination mechanisms become embedded in cluster-level governance. The Energy Vaasa case therefore illustrates how digital renewal may stall even where firms possess technological capabilities and strategic ambition, but cluster-level coordination mechanisms remain underdeveloped.

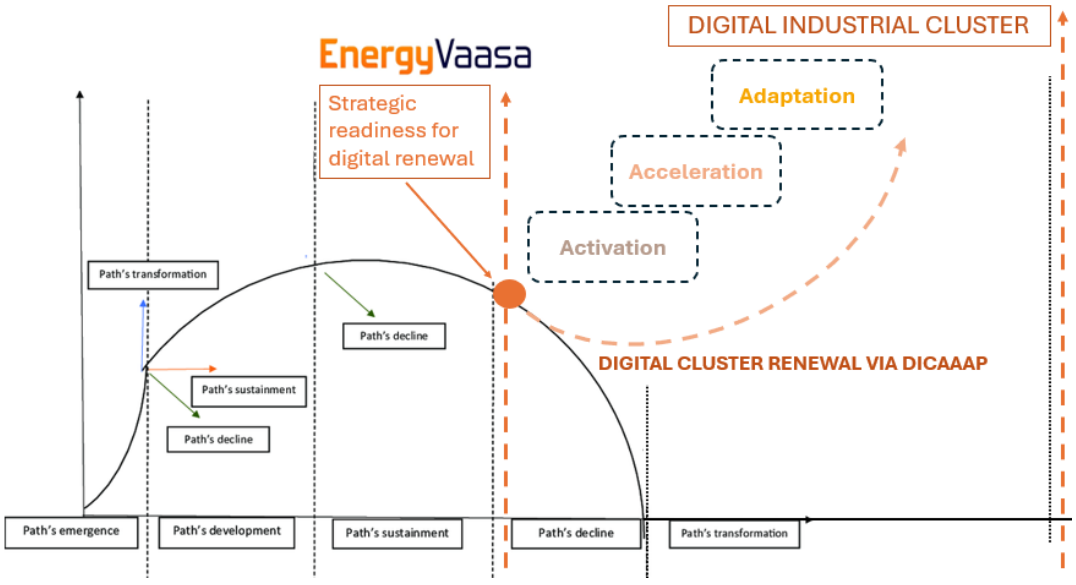


**Figure 10.** Analytical positioning of Energy Vaasa within the cluster life cycle and the staged DICAAAP pathway toward Digital Industrial Cluster transformation (author's elaboration based on Ostapenko et al., 2022).

Figure 10 illustrates the analytical positioning of Energy Vaasa within the cluster life-cycle trajectory and its relationship to the DICAAAP transformation pathway. The cluster is

located at the transition between the sustainment phase and the early decline trajectory, where renewal pressures become increasingly visible but coordinated transformation mechanisms remain underdeveloped. Although actors recognise maturity and express ambitions related to digitalisation and cross-regional collaboration, the cluster has not yet fully entered the DICAAAP pathway.

Entry into this pathway requires several governance conditions. These include shared life-cycle diagnostics, coordinated digital infrastructure, and clearly defined orchestration roles capable of sustaining collective participation. In the current configuration, these conditions remain only partially developed. Energy Vaasa therefore occupies a stage of strategic readiness for digital renewal, where awareness of renewal pressures exists but has not yet translated into collectively embedded coordination practices.

This positioning helps explain why digital transformation remains uneven at the cluster level. Individual firms demonstrate significant technological capability, yet these capabilities are not consistently translated into shared coordination structures across the cluster. Without common diagnostics, operational digital infrastructure, and institutionalised governance arrangements, digital initiatives remain episodic rather than becoming embedded in routine cluster coordination.

Table 6 summarises the governance conditions identified across the DICAAAP stages and situates Energy Vaasa within this staged progression. The table shows how incomplete development at earlier stages constrains advancement toward a fully developed Digital Industrial Cluster.

**Table 6.** Governance Conditions and Stage Positioning in the DICAAAP Framework

| Stage / Condition | Stage Logic | Governance Gap | Required Governance Conditions | Empirical Position |
|---|---|---|---|---|
| **Strategic Readiness (Precondition)** | Align diagnostics before mobilisation | Indicators used symbolically; participation boundaries unclear; no shared metrics | Shared life-cycle metrics, transparent cluster scope, explicit renewal mandate | Unconsolidated |
| **Activation** | Mobilise actors around renewal | Fragmented diagnostics; role-dependent interpretations | Shared monitoring routines and a common renewal narrative | Fragmented |
| **Acceleration** | Scale digital coordination across the cluster | Weak orchestration; limited shared infrastructure; uneven participation | Defined orchestration roles, participation rules, operational digital systems | Selective |
| **Adaptation** | Stabilise digital coordination through governance | Informal trust-based coordination; no embedded mandates or digital KPIs | Integrated governance structures, accountability mechanisms, long-term strategic embedding | Pre-adaptive |
| **Digital Industrial Cluster (DIC Outcome)** | Stabilised digital governance | — | Consolidation of governance conditions across all stages | Not achieved |

Overall, the findings indicate that Energy Vaasa is positioned between fragmented Activation, limited Acceleration, and pre-adaptive coordination. Actors recognise renewal pressures and articulate digital ambitions, yet shared diagnostics, coordinated infrastructure, and institutionalised governance mechanisms remain only partially developed. As a result, digital transformation does not consolidate at the cluster level.

The case therefore shows that progression within the DICAAAP framework depends less on technological availability than on the development of governance conditions that enable collective coordination. Digital renewal becomes sustainable only when diagnostic alignment, coordination mechanisms, and institutionalised governance routines develop together across the stages of the transformation pathway.

# 7 Discussion, contributions, and implications

This chapter interprets the empirical findings in relation to Cluster Life Cycle (CLC) theory, evolutionary economic geography, digital transformation research, and Digital Industrial Cluster (DIC) scholarship. Chapter 6 positioned Energy Vaasa between fragmented Activation, selective Acceleration, and pre-adaptive coordination within the DICAAAP framework. Building on this analysis, the discussion examines how the findings contribute to existing theoretical perspectives and clarifies the governance mechanisms through which digital cluster renewal unfolds.

The analysis indicates that digital cluster renewal depends less on technological adoption alone and more on the development of governance arrangements that coordinate collective action. While digital technologies and capabilities may be available at the firm level, cluster-level transformation requires institutional structures that align actors, establish coordination mechanisms, and sustain collaborative initiatives over time. The Energy Vaasa case therefore provides insight into how mature clusters pursue digital transformation and why such processes often remain incomplete.

## 7.1 Discussion of findings

The empirical findings show that while Energy Vaasa displays structural maturity and strong industrial capabilities, its progression toward digital renewal remains mediated by uneven governance alignment. Structural maturity generates awareness of renewal pressures, but governance conditions determine whether this awareness translates into coordinated transformation.

### 7.1.1 Governance-mediated life cycle progression

Cluster Life Cycle theory suggests that mature clusters face increasing risks of stagnation, lock-in, and declining adaptability (Hassink, 2010; Martin & Sunley, 2011; Menzel &

Fornahl, 2010). The Energy Vaasa case supports this structural diagnosis, as actors widely recognised maturity pressures and the need for renewal.

However, awareness of maturity did not automatically generate coordinated transformation. Respondents acknowledged the need for continued development, yet renewal remained fragmented because shared diagnostics, monitoring routines, and institutionalised governance mechanisms were absent.

These findings suggest that life-cycle progression is mediated by governance conditions. Structural maturity generates awareness pressures, but governance alignment converts this awareness into coordinated renewal. Cluster renewal therefore depends not only on structural dynamics but also on governance arrangements that align actors around shared diagnostics, coordination mechanisms, and collective transformation goals.

### 7.1.2 Narrative recognition versus institutional mobilisation

Adaptive renewal literature highlights the importance of narratives, agency, and cognitive reframing in enabling cluster transformation (König & Brenner, 2025; Ostapenko et al., 2022). In the Energy Vaasa case, renewal narratives were clearly present. Actors frequently referred to digitalisation, the green transition, and cross-regional collaboration as potential drivers of future growth.

Yet these narratives were not embedded in structured monitoring systems, shared metrics, or formal coordination mechanisms. As a result, awareness of renewal pressures remained distributed across actor groups rather than consolidated into shared diagnostic alignment.

The findings therefore reveal a distinction between narrative recognition and institutional mobilisation. Narratives may signal awareness of change, but mobilisation requires governance structures capable of translating shared awareness into coordinated

action. Without such institutional alignment, renewal narratives remain aspirational rather than operational.

### 7.1.3 Path renewal and the missing coordination architecture

Evolutionary economic geography explains cluster renewal through processes of branching and recombination of capabilities (Boschma & Frenken, 2006; Trippl et al., 2015). These mechanisms clarify how new development paths may emerge from existing knowledge bases.

The Energy Vaasa case demonstrates, however, that path emergence alone does not ensure systemic transformation. Digital initiatives remained selective and project based. Although firms possessed digital capabilities and expressed interest in collaborative initiatives, cluster-level scaling did not consolidate because orchestration roles, participation rules, and shared coordination infrastructure were insufficiently developed.

These findings suggest that path renewal requires governance scaffolding capable of stabilising emerging initiatives. Branching becomes transformative only when coordination structures enable collective alignment and cumulative learning. Without institutional consolidation, renewal efforts remain episodic and fail to generate sustained cluster-level transformation.

### 7.1.4 Digital transformation as governance alignment

Digital transformation research often emphasises technological adoption and ecosystem orchestration (Verhoef et al., 2021; Vial, 2019). The findings confirm that technological availability alone does not guarantee systemic transformation.

In the Energy Vaasa ecosystem, firm-level digital capabilities were already present. Nevertheless, cluster-level digital coordination remained limited. Platforms and AI tools

were discussed as potential solutions but had not become embedded in routine governance practices.

Platform governance scholarship emphasises that digital infrastructures generate value only when supported by clear participation rules, coordination mechanisms, and accountability structures (Jacobides et al., 2018; Srnicek, 2017). The Energy Vaasa case confirms this insight at the cluster level. Digital cluster transformation is constrained less by technological readiness than by the absence of governance arrangements capable of coordinating collective participation.

Digital transformation therefore emerges as an institutional coordination process rather than a purely technological one.

### 7.1.5 Embeddedness and the limits of informal coordination

Relational embeddedness has long been recognised as a strength of mature industrial clusters (Bathelt et al., 2004; Boschma, 2005). In Energy Vaasa, trust-based relationships supported collaboration and enabled project-based cooperation.

However, trust often substituted for formal governance rather than complementing it. Informal coordination sustained cooperation but limited scalability. Digital initiatives depended largely on voluntary engagement rather than institutionalised governance structures.

This situation reflects a pre-adaptive condition. Collaboration remains stable, yet digital coordination has not been institutionalised. Relational strength alone does not guarantee adaptive capacity. Without formal roles, monitoring routines, and embedded accountability mechanisms, digital transformation remains incomplete.

These observations highlight the importance of governance alignment in enabling digital cluster renewal, a theme further elaborated in the theoretical contributions of this study.

## 7.2 Theoretical contributions

This study contributes to research on cluster renewal, digital transformation, and Digital Industrial Clusters by developing and empirically grounding the DICAAAP framework as a governance-based pathway for digital cluster transformation. By integrating cluster life cycle theory, evolutionary economic geography, and digital transformation research, the study advances four theoretical contributions.

1. **Reframing cluster life cycle progression as governance-mediated**

Cluster Life Cycle theory traditionally explains cluster evolution through structural forces such as market dynamics, technological change, and industrial restructuring. The findings of this study suggest that stage progression is not determined solely by structural dynamics.

In the Energy Vaasa case, actors recognised the pressures associated with cluster maturity and the need for renewal, yet this awareness did not translate into coordinated transformation. Renewal remained fragmented because shared diagnostics, monitoring routines, and coordination mechanisms were not institutionalised.

This study therefore reframes cluster life cycle progression as governance-mediated. Structural maturity generates pressure for change, but collective renewal depends on institutional arrangements capable of aligning actors around shared interpretations, priorities, and coordination mechanisms. Cluster evolution should thus be understood not only as an economic process but also as an institutional coordination process in which governance structures enable or constrain renewal.

**2. Introducing Strategic Readiness as a precondition for mobilisation**

This study introduces Strategic Readiness as a critical precondition for coordinated cluster renewal. Strategic Readiness refers to the degree of diagnostic alignment among cluster actors prior to large-scale mobilisation. It includes a shared understanding of the cluster's development stage, common metrics for assessing cluster performance, and agreement on strategic priorities for transformation.

The findings demonstrate that renewal narratives alone do not generate coordinated action. In Energy Vaasa, actors frequently referred to digitalisation, the energy transition, and international collaboration as future growth drivers. However, these narratives were not supported by shared monitoring systems or collective diagnostic processes.

Strategic Readiness therefore clarifies an important mechanism in cluster renewal: mobilisation becomes possible only when actors share diagnostic frameworks that define the problem and legitimise collective action. By identifying diagnostic alignment as a distinct precondition for mobilisation, this study explains why renewal initiatives often remain aspirational rather than operational.

### 3. Specifying governance architecture for path stabilisation

Research on regional development and path renewal explains how new economic trajectories emerge through branching and recombination of capabilities. However, the institutional structures required to stabilise these trajectories remain under-specified.

The findings demonstrate that the emergence of digital initiatives does not automatically produce sustained transformation. In the Energy Vaasa case, firms possessed digital capabilities and expressed interest in collaboration, yet cluster-level scaling remained selective and project-based.

The DICAAAP framework addresses this gap by specifying the governance architecture required for path stabilisation. Digital renewal is conceptualised as a staged process

involving activation of shared diagnostics, acceleration of coordinated initiatives, and adaptation through institutional consolidation. Transformation therefore depends not only on technological capability but also on governance mechanisms that enable sustained coordination across firms and institutions.

**4. Operationalising the pathway toward Digital Industrial Clusters**

The DICAAAP framework operationalises the transformation pathway toward Digital Industrial Clusters by conceptualising digital cluster renewal as a staged governance process involving Activation, Acceleration, and Adaptation. In doing so, it shifts Digital Industrial Cluster research from descriptive conceptualisation toward explaining the process through which digital cluster transformation unfolds in mature industrial contexts.

Each stage represents a distinct coordination challenge, and Digital Industrial Cluster formation emerges only when governance conditions consolidate across these stages.

Taken together, these contributions demonstrate that digital cluster renewal is not primarily a technological transition but an institutional consolidation process. The DICAAAP framework therefore provides an analytical lens for explaining how governance alignment enables or constrains digital transformation in mature industrial clusters.

## 7.3 Managerial and policy implications

The findings suggest that digital transformation in mature industrial clusters should be approached primarily as a governance challenge. While digital technologies and platforms can support collaboration, their effectiveness depends on institutional arrangements that coordinate participation, define roles, and sustain collective action over time.

For cluster managers, the results highlight the importance of establishing shared diagnostic frameworks that allow actors to collectively assess the cluster's development stage and renewal priorities. Without shared monitoring practices, perceptions of cluster

maturity and strategic direction remain fragmented across actor groups. Regular cluster diagnostics—including assessments of collaboration activity, innovation outputs, and membership dynamics—can help align actors around common strategic priorities and strengthen readiness for coordinated transformation.

A second implication concerns the need to strengthen cluster orchestration capacity. Digital coordination tools alone do not generate collaboration; active orchestration remains necessary. Cluster management organisations must actively facilitate interaction by connecting firms with potential partners, coordinating joint innovation projects, and translating firm-level needs into cluster-level initiatives. Effective orchestration ensures that digital initiatives generate tangible value and become embedded in everyday collaboration practices.

Third, digital initiatives should prioritise practical coordination value for firms, particularly small and medium-sized enterprises. Firms are more likely to adopt digital coordination mechanisms when these tools support concrete collaboration needs such as partner discovery, project matchmaking, and access to external innovation networks. Platforms designed around operational collaboration functions are therefore more likely to sustain participation than those focused primarily on visibility or communication.

The findings also carry implications for policymakers responsible for cluster development and regional innovation strategies. Public policy frequently emphasises investments in digital technologies and innovation infrastructure. However, the results indicate that governance capacity within cluster organisations is equally critical. Policymakers should therefore complement technological investments with support for cluster management capabilities, including coordination skills, facilitation capacity, and long-term governance development.

Finally, policymakers can strengthen cluster renewal by supporting cross-regional and international collaboration infrastructures. Digital coordination mechanisms enable

clusters to connect with external innovation ecosystems and participate in broader research and innovation networks. Policy programmes that encourage inter-cluster collaboration, joint innovation projects, and participation in international initiatives may therefore enhance the capacity of clusters to pursue digital transformation.

## 7.4 Implications for Energy Vaasa

The findings indicate that Energy Vaasa possesses strong industrial capabilities, established collaboration networks, and a trusted cluster management organisation. However, incomplete governance consolidation across the stages of the DICAAAP framework still constrains digital transformation within the cluster.

First, cluster actors should establish shared diagnostic practices that allow them to collectively assess the cluster's development stage and renewal priorities. Currently, perceptions of cluster maturity and renewal needs remain role dependent and lack systematic monitoring routines. Regular cluster-level diagnostics based on collaboration activity, innovation outputs, and participation dynamics could strengthen strategic alignment and improve readiness for coordinated transformation. Cluster actors should rely on transparent operational indicators rather than figures used primarily for marketing or communication purposes, which may present an overly positive image of cluster performance and therefore provide limited diagnostic value.

Second, cluster management can further strengthen orchestration capacity for digital coordination. Technology Centre Merinova already connects firms, universities, and public actors and therefore occupies a central intermediary position within the ecosystem. By expanding this role toward more explicit orchestration of digital initiatives, including partner matchmaking, collaborative innovation projects, and cross-regional partnerships, Merinova can help translate digital ambitions into operational cluster-level practices.

Third, digital initiatives should focus on delivering clear coordination value for participating firms. Interviewees highlighted the importance of tools that support partner search,

project matchmaking, and access to external collaboration opportunities. Platforms designed around these practical functions are more likely to sustain engagement than systems focused mainly on communication or visibility. Clearly articulating the benefits of participation may also encourage firms from the wider regional ecosystem to engage with cluster-level digital initiatives and support gradual expansion beyond the existing core network.

Fourth, Energy Vaasa should further institutionalise governance routines that support digital coordination. Collaboration within the cluster currently relies strongly on trust-based relationships and project-level interaction. While relational embeddedness remains a key strength of the ecosystem, reliance on informal coordination alone can limit scalability and increase the risk of institutional lock-in. By complementing relational collaboration with transparent governance routines, defined participation rules, and clearer coordination responsibilities, cluster actors can maintain trust while enabling broader and more sustainable collaboration.

Finally, Energy Vaasa can expand cross-regional and international collaboration as part of its digital development strategy. Digital coordination mechanisms can strengthen connections with external innovation ecosystems and support greater participation in international research and innovation programmes.

At the same time, the analysis highlights a potential tension between the strong territorial identity of the Energy Vaasa brand and ambitions for digitally enabled cross-regional expansion. The cluster's identity remains strongly associated with Vaasa as a geographic location and industrial hub. While this territorial embeddedness represents an important strength, it may also create governance challenges as collaboration increasingly extends beyond regional boundaries. Addressing this tension requires clarifying how the Energy Vaasa identity can evolve from a place-based industrial cluster toward a broader coordination platform connecting actors across multiple regions.

## 7.5 Limitations

This study has several limitations that define the scope of its conclusions.

First, the research is based on a single case study of Energy Vaasa. While analytically informative, the findings support analytical rather than statistical generalisation.

Second, the study examines a cluster positioned between transformation stages rather than one that has fully achieved Digital Industrial Cluster consolidation. The analysis therefore identifies governance conditions through transitional dynamics rather than through observation of complete stage progression.

Third, the study identifies governance conditions through qualitative analysis of interview data. Future research could refine measurement approaches and provide quantitative validation of the proposed framework.

Fourth, the institutional context of the study is European and shaped by regional innovation policy structures. Different institutional environments may therefore produce alternative patterns of cluster renewal and governance development.

## 7.6 Future research

Future research can extend this work in several directions.

First, comparative multi-case studies across sectors and regions could examine whether the governance conditions identified in this study operate consistently across different institutional and industrial contexts.

Second, longitudinal research could track clusters progressing across DICAAAP stages over time, providing direct evidence of governance consolidation and stage transition dynamics.

Third, future studies could develop quantitative indicators to operationalise the governance conditions proposed in this thesis, including Strategic Readiness, diagnostic alignment, and stage consolidation.

Fourth, further research may examine digital leadership capabilities within cluster management organisations. The governance-dependent perspective advanced in this study suggests that orchestration competence, strategic coordination, and institutional design capacity play an important role in successful digital renewal.

Finally, future research may explore how governance-dependent digital transformation interacts with broader structural transitions, including energy transition pressures, geopolitical change, and multi-scalar innovation dynamics.

## 7.7 Conclusion

This study examined how mature industrial clusters pursue digital renewal through the DICAAAP framework. The findings show that digital transformation in clusters depends less on technological availability than on the development of governance structures that coordinate collective action.

The Energy Vaasa case illustrates a transitional condition in which actors recognise renewal pressures and articulate digital ambitions, yet shared diagnostics, orchestration capacity, and institutional governance mechanisms remain incomplete. As a result, digital initiatives emerge but remain fragmented rather than fully embedded in cluster-level coordination.

Digital Industrial Cluster formation therefore represents a staged governance process rather than a technological inevitability. The DICAAAP framework demonstrates that digital transformation in mature clusters requires diagnostic alignment, coordinated

orchestration of collaborative initiatives, and institutionalisation of governance mechanisms capable of sustaining collaboration over time.

By foregrounding governance as the central mechanism of cluster renewal, this study advances understanding of how mature industrial ecosystems organise and sustain digital transformation processes.

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# Appendices

The appendices provide supporting empirical material, analytical syntheses, and triangulation evidence used in the interpretation of findings. They are included to enhance transparency and traceability of the qualitative analysis.

# Appendix 1. DICAAAP Semi-Structured Interview Guide


## Semi-Structured Interview Guide

**Background & Role**

- Can you briefly describe your role within Energy Vaasa?
- How long have you been involved with the cluster?

**Activation (Diagnosis & Mobilisation)**

- How would you describe Energy Vaasa's current stage of development?
- What pressures or challenges are most critical right now?
- How is digital transformation currently discussed at cluster level?
- Where do you see coordination gaps or barriers?

**Acceleration (Scaling & Coordination)**

- Which digital initiatives currently create value across firms?
- How are SMEs included (or excluded)?
- How are decisions made around shared digital tools or platforms?
- What governance challenges emerge as initiatives scale?

**Adaptation (Institutionalisation & Renewal)**

- Have digital practices become routine at cluster level?
- How are responsibilities for digital coordination defined?
- What mechanisms support learning and adjustment over time?
- How prepared is the cluster for cross-regional collaboration?

**Reflection**

- What would need to change for digital transformation to support long-term renewal?

## Appendix 2. Sensitising Concepts and Illustrative Indicators

This appendix outlines the sensitising concepts and illustrative indicators used to guide reflexive thematic analysis. The DICAAAP framework informed interpretation through stage-specific analytical lenses rather than as a fixed coding scheme or evaluative tool.

**Analytical use:** The concepts supported initial familiarisation and coding while allowing inductive themes to emerge. They guided interpretation of how digital transformation was framed, coordinated, and sustained at cluster level, without assigning numerical scores or predefined maturity levels.

| Stage | Sensitising Concept | Illustrative Empirical Indicators | Analytical Interpretation |
|---|---|---|---|
| **Activation** | Lifecycle awareness | References to maturity, stagnation, decline, loss of momentum, or renewal pressure | Indicates whether actors recognise structural cluster life cycle challenges rather than framing issues as temporary, firm-specific, or purely market-driven |
| | Coordination failure | Descriptions of silos, fragmented initiatives, duplicated efforts, or lack of shared priorities | Signals the absence of a shared problem definition and weak collective sense-making at the cluster level |
| **Acceleration** | Critical mass | References to scaling beyond pilots, multi-actor uptake, or participation limits | Reflects whether digital initiatives move from isolated experimentation toward cluster-level collective action |
| | Platform governance | Mentions of rules, standards, ownership, decision rights, or inclusion mechanisms | Indicates the presence or absence of coordination and orchestration mechanisms required for collective scaling |
| **Adaptation** | Institutionalisation | References to formal roles, routines, KPIs, embedded responsibilities, or long-term mandates | Signals whether digital coordination is stabilised within governance and strategy rather than remaining project-based |
| | Learning mechanisms | Mentions of feedback loops, review practices, adjustment over time, or organisational learning | Reflects the cluster's capacity for continuous adjustment and sustained renewal beyond initial transformation efforts |

## Appendix 3. Illustrative DICAAAP diagnostic and intervention menu

| Stage | Analytical focus | Illustrative diagnostic questions | Typical coordination issues observed |
|---|---|---|---|
| **Activation** | Shared diagnosis and mobilisation | ▪ Is there a shared understanding of cluster maturity and renewal risks?<br>▪ Are digital initiatives framed as collective renewal mechanisms rather than isolated firm projects?<br>▪ Are coordination failures and governance gaps openly recognised? | Fragmented digital projects; weak shared renewal narrative; digitalisation treated as technical or firm-specific |
| **Acceleration** | Scaling and coordinated implementation | ▪ Which digital infrastructures or platforms are gaining critical mass?<br>▪ Are SMEs and peripheral actors meaningfully included?<br>▪ Are rules for participation, data sharing, and coordination responsibility explicit? | Pilot fatigue; limited participation; unclear ownership or orchestration responsibilities |
| **Adaptation** | Institutionalisation and stabilisation | ▪ Are digital coordination practices embedded in cluster strategy and routines?<br>▪ Are governance roles formalised and institutionally sustainable?<br>▪ Do learning and feedback mechanisms exist? | Reliance on temporary projects; governance overload; risk of regression to informal coordination |

## Appendix 4. Illustrative DICAAAP Stage Indicators Framework

This framework presents illustrative indicators intended to guide analytical interpretation rather than to function as a prescriptive measurement or maturity assessment tool.

| Stage | Dimension | Example Indicators |
|---|---|---|
| **Activation** | Strategic alignment | Shared vision documents |
| | Diagnosis | Explicit life cycle framing |
| **Acceleration** | Orchestration and participation | Number/diversity of firms |
| | Governance mechanisms | Data-sharing rules |
| **Adaptation** | Institutionalisation | Formal roles, KPIs |
| | Resilience | Ability to adapt to shocks |

# Appendix 5. Participant Information Sheet & Consent Form

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## Participant Information Sheet & Consent Form

You are invited to take part in an academic research interview for a master's thesis at the University of Vaasa. The study explores how industrial clusters (such as Energy Vaasa) can adopt **digital platforms** to support renewal, inter-regional cooperation, and digital scaling.

**Title of the Study:**
DICAAAP: A Strategic Framework for Digital Renewal of Industrial Clusters

| | |
|---|---|
| **Degree Programme:** | Master's Programme in Strategic Business Development |
| **Researcher Name:** | Maissa Ftiti, Master's Student, University of Vaasa |
| **Supervisor:** | Jukka Partanen, Associate Professor, University of Vaasa |

### Why You Were Invited

You are part of a relevant organization or stakeholder group (e.g., cluster actor, innovation expert, or company) whose perspective is valuable in shaping this framework.

### What Does Participation Involve?

- A **voluntary interview** lasting approximately **15–45 minutes**
- Conducted **face-to-face**
- With your permission, the interview will be **audio recorded** for analysis
- No sensitive personal data is collected

### How Will Your Data Be Used?

- The interview will be **transcribed and anonymized**
- All data will be stored on the University of Vaasa's servers securely used only for academic purposes (see Appendix 1)
- Your **name or organization** will not be published
- Data will be kept for **5 years** and then deleted securely
- You can withdraw at any time. If you withdraw, data already collected may still be used in anonymized form.

### What Are the Benefits?

- Your input helps shape a digital cluster model that may benefit other organizations like yours across Europe. Findings may also inform policy and innovation strategy.

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## Data Protection Notice

**This study complies with the EU General Data Protection Regulation (GDPR) and the Finnish Data Protection Act. Your personal data will not be shared with third parties and will be used only for academic research. No compensation is provided for participation. The University of Vaasa is the data controller**

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## Consent Statement

By signing below, you agree that:

- You understand the purpose of the study
- You voluntarily agree to participate and uncompensated
- You allow audio recording
- You know you can stop or withdraw at any time

## Please Check:

☐ I agree to participate in this interview
☐ I allow audio recording of the interview
☐ I understand my data will be anonymized and securely stored

**Participant Name**: _____

**Signature**: _____

**Date & Place**: _____

---

## Contact information:

**Maissa Ftiti**
u96352@student.uwasa.fi

**Jukka Partanen**
jukka.partanen@uwasa.fi

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**Appendix 1 Data Storage and Access Information**

All data collected through this study will be received and securely stored on the University of Vaasa's servers.

Access to the data will be strictly limited to the researcher, the thesis supervisor, and authorized University of Vaasa staff involved in thesis supervision, assessment, or academic compliance procedures.

The data will be used solely for academic research purposes. All handling of personal data will follow the principles of the EU General Data Protection Regulation (GDPR) and the Finnish Data Protection Act.

No personal data will be shared with external parties. Participants may withdraw consent and request data deletion at any point prior to anonymization.

## Appendix 5.0. Case Context and Cluster Management Role

| Theme | Illustrative quote | Actor |
|---|---|---|
| Cluster management mandate | "Merinova is the cluster management organization of Energy Vaasa.<br><br>We have both a strategic and operational role in developing the cluster. Strategically, we coordinate the cluster's direction, strengthen RDI collaboration, and align our work with regional and national clean transition goals.<br><br>Operationally, we connect members, facilitate joint projects, and promote collaboration and international visibility through activities like organizing several of the seminars at Energy Week and ecosystem visits.<br><br>We also run several projects on behalf of the cluster and apply for national and EU funding to support its development.<br><br>Merinova ensures that Energy Vaasa meets the ECEI Gold Label standards, following international best practices in cluster management and continuous improvement." | MTI2 |

## Appendix 5.1. Activation: Illustrative Case Quotes

| Theme | Illustrative quote | Actor |
|---|---|---|
| Lifecycle maturity awareness | "Energy Vaasa is currently in a growth and renewal phase (2025–2027), focusing on strengthening RDI collaboration, resilience, and attractiveness for investments." | MTI2 |
| Maturity framing without decline narrative | "Our cluster is well developed. There is a lot of space for improvement, and companies are working together, so you can't say it's declining. It is a mature phase, but we need to find new ways to deepen collaboration. " | MTI4 |
| Diagnostic uncertainty | "The number of companies is one indicator… I don't know how these are monitored at the moment." | MTI0 |
| Waiting logic +<br>External trigger dependence | "I would describe it as sustaining and waiting for the green transition to trigger growth again. The individual companies are established and are growing organically in volume, and there is also gradual growth in employment. However, the cluster itself is not growing significantly in terms of expanding the scope of products or deliveries." | UMTI3 |
| Relational maturity and sustaining mode | "Very mature: people know each other, established ways of working, everyone included. Currently sustaining/growing mode...Not declining yet but needs new growth paths to avoid stagnation." | LCI5 |
| Stagnation concern (SME) | "There may be some stagnation." | SCI11 |

**Note:** Themes reflect analytical categories developed in Chapters 5 and 6 and are provided here for illustrative and transparency purposes.

## Appendix 5.2. Acceleration: Illustrative Case Quotes

| Theme | Illustrative quote | Actor |
|---|---|---|
| Digital ambition | "We are the first cluster in Finland to develop an AI-assisted digital platform designed to strengthen collaboration and support the creation of joint RDI initiatives and projects. The platform will help our members connect more effectively, share knowledge, and identify new opportunities for cooperation." | MTI2 |
| Missing cluster-level infrastructure | "Large corporations have internal digital platforms and use digital tools internally, but for the cluster as a whole, there is no such platform." | MTI4 |
| Facilitation and coordination constraints | "The problem is facilitation and how collaboration is done, because everyone has limited time. It must be easy to use and easy to find opportunities." | MTI4 |
| Limited use of digitalisation + Digital visibility without operational coordination | "Very little at cluster management level. We are digitally visible through platforms and portals, but we do not actively use digitalisation for coordination... We use existing tools like Teams for one-to-one communication with companies or the university, but activities remain mostly in-person. These tools do not support true cluster management." | UMTI3 |
| Lack of transparency and visibility | "The list of cluster members has not been public (some companies yes but not all)." | MTI0 |
| Absence of shared digital collaboration routines | "There is no digital collaboration at the moment." | MTI0 |
| Perceived exclusion and limited participation | "Companies have not been included enough before, that will be fixed in new strategy" | MTI0 |
| Geographic framing limits collaboration scope | "The Energy Vaasa region has been defined Vaasa, I think there will be more collaboration with companies outside Vaasa region in future." | MTI0 |
| SME demand for coordination tools | "Partner search and project matchmaking are the most important." | SCI11 |
| Firm-level scaling limits | "Provide showcases and examples of what works – though not everything scales to smaller firms." | LCI5 |
| Need for neutral orchestration | "Merinova or similar actors should lead." | LCI5 |

## Appendix 5.3. Adaptation: Illustrative Case Quotes

| Theme | Illustrative quote | Actor |
|---|---|---|
| Trust as prerequisite for collaboration | “Trust. People are still people. Building trust is the key at the beginning. Digital platforms can feel not real, so you need due diligence and trust-building.” | MTI4 |
| In-person interaction as the default trust mechanism | “Trust is easier to build through in-person interaction than purely digitally.” | UMTI3 |
| Limits of replicating trust digitally | “Traditional work relies on personal interaction and trust... not easy to replicate digitally.” | MTI2 |
| Trust-first logic over formal systems | “You need to know the people you do business with. Technical solutions come after relationships and trust.” | LCI5 |
| Absence of formal rules and routines | “We apply the same principles to our digital systems as to our cluster management, but clear rules need to be agreed early on.” | MTI2 |
| Governance incompleteness | “At the moment, I think there are more basic things that need to be fixed.” | MTI0 |
| Neutrality and leadership ambiguity | “A dominant firm should not lead cluster-level digital coordination.” | LCI5 |
| Cluster boundary uncertainty under digitalisation | “If the cluster becomes more digital, it will automatically expand its geographical presence. At that point, it may no longer be appropriate to call it a ‘cluster’ but rather an ecosystem.” | UMTI3 |
| Cluster boundary uncertainty under digitalisation | “Clusters are geographically bound. If not geographically bound, should stop using 'cluster' and use 'ecosystem'... strategy must come first before digital transformation.” | UMTI3 |
| Limits of trust-based inclusion | “Mutual trust is at a good level, but... difficult for smaller company to get involved.” | SCI11 |
| Informal governance as substitute for institutions | “Long history of less formal governance, more trust, collaboration. Put expert people together... trust is key, not power, size or budget.” | RPI7 |

## Appendix 6.1. Activation: Analytical Synthesis Linking Empirical Patterns and Theoretical Anchors

| **Empirical pattern (from Ch. 5)** | **Analytical interpretation (Ch. 6.1)** | **Theoretical anchor** |
|---|---|---|
| Role-dependent life cycle assessments | Fragmented Activation: sense-making remains individualised | Martin & Sunley (2011); Ostapenko et al. (2022) |
| No shared indicators or monitoring routines | Diagnostic under-institutionalisation | Hassink (2010) |
| Avoidance of decline framing | Identity protection delays renewal mobilisation | Martin & Sunley (2011) |
| Renewal framed as externally triggered | Wait-and-see equilibrium | König & Brenner (2025) |

**Note:** Appendix 6.1 summarises how empirical patterns identified in Chapter 5 were interpreted analytically in Section 6.1 and linked to relevant theoretical perspectives.

## Appendix 6.2 – Acceleration: Governance Gaps Limiting Cluster-Level Coordination

| Observed condition | Missing governance mechanism | Analytical implication |
|---|---|---|
| Digital platforms discussed but not operationalised | Orchestration routines | Acceleration remains aspirational |
| SME coordination demand unmet | Shared value anchoring | Uneven participation |
| Firm-level digitalisation dominates | Cluster-level infrastructure | Fragmented scaling |
| Limited transparency of collaboration outcomes | Accountability mechanisms | No accumulation effects |

**Note:** Appendix 6.2 synthesises the key governance gaps that constrain the consolidation of Acceleration at cluster level.

## Appendix 6.3. Adaptation: Synthesis of the Pre-Adaptive Coordination Condition

| Dominant coordination mode | Limitation | Adaptation implication |
|---|---|---|
| Trust-based collaboration | Not scalable in digitally mediated coordination | Institutionalisation remains incomplete |
| Informal governance | Limited institutional durability | Transformation remains episodic |
| Neutrality concerns | Orchestration leadership ambiguity | Orchestration vacuum |
| Boundary uncertainty | Organisational boundary uncertainty | Pre-adaptive state |

**Note:** Appendix 6.3 summarises the governance characteristics underlying Energy Vaasa's pre-adaptive coordination condition.

## Appendix 6.4. Triangulation Evidence from External Informants

| | Theme | Key quote | Actor | Contribution to analysis |
|---|---|---|---|---|
| **Activation** | Diagnostic Alignment and Life cycle Monitoring | "Every 3 years analysis: turnover, exports, employees, companies, innovation (R&D +131%, patents) ... outperforms national context." | (EACI9) | These quotations reinforce the interpretation in Section 6.1 that Energy Vaasa exhibits life cycle awareness without life cycle governance, supporting the concept of diagnostic under-institutionalisation identified in the analysis. |
| | | "Internally, companies use sophisticated tools, but between companies' collaboration remains old-fashioned: email, spreadsheets, Teams." | (MCOI6) | |
| **Acceleration** | Orchestration, Value Anchoring, and Scaling | "Digital platforms only work if they create everyday value." | (MCOI6) | These quotations support the interpretation in Section 6.2 that digital ambition alone does not produce Acceleration. They reinforce the concept of value anchoring and demonstrate that active orchestration is a necessary condition for collective scaling. |
| | | "Use design-thinking-based user research to understand daily context, needs, and what creates value" | | |
| | | "The key evaluation point is practical value: does it deliver concrete results?" | | |
| | | "Barriers are change resistance and tool fatigue – people are tired of learning many different platforms." | | |
| | | "They organised an innovation challenge with large companies (Vestas, Siemens and Gamesa) ... Cluster managers then found SMEs that could work on solutions...This would never have happened without cluster managers acting as facilitators." | (EPI1) | |
| | | "We would love to cooperate. We have energy clusters in Romania." | (EACI9) | |
| **Adaptation** | Governance Continuity, Renewal Risk, and Institutionalisation | "Platform never 'done' continuous development..." | (MCOI6) | These quotations reinforce the interpretation in Section 6.3 that Energy Vaasa remains in a pre-adaptive condition, where trust-based coordination substitutes for formal governance but fails to scale or stabilise digital transformation. |
| | | "Cluster managers need clear vision: where to take cluster in 5-10 years." | (EPI1) | |
| | | "We lag on digitalisation. Our clusters have reached maturity, and something must happen now or they will decline and die, not just in Romania but across Europe...Digitalisation may be an instrument to extend cluster life cycles." | (EACI9) | |
| | | "I do not see major trust issues. Clusters are ethical organisations. You have to take some risk." | | |