

Industrializing Innovation Globally

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Executive Summary

Successfully pursuing ambitious and comprehensive sustainability goals requires rapidly industrializing and deploying clean technologies. Meticulously curated networks provide one such vessel to catalyze high-quality industrialization of innovation [1]. Research has extensively validated the benefits of collaboration in innovation ecosystems, which have traditionally been linked to specific geographic regions. Building on its success in Germany, PEM Motion has transferred and adapted its strategic expertise in ecosystem development. It actively supports partners across North America, Africa, Asia, and Europe to achieve rapid and successful sustainable innovation. Collaboration with various stakeholders has laid the foundation for ecosystems focused on shaping the future of mobility and establishing local innovation hubs as thriving sites for cleantech industrialization. Through a systematic and strategic approach to launching local innovation ecosystems and leveraging existing ventures, PEM Motion proposes a novel business model framework that introduces a global dimension to ecosystem management.

Keywords: global, business model, industrialization, strategy, sustainability

1 Challenges to Innovation in the Race to a More Sustainable Future

Innovation has been and remains a fundamental driving force for human development, particularly in the face of myriad societal challenges. With each passing innovation cycle, the pace and impact of innovation have only accelerated. However, the adverse effects of climate change remain a daunting challenge, with no holistic and practical solutions discovered. Against this backdrop, it has become increasingly clear that the technological developments of the 21st century must be closely aligned with the goals of the Paris climate treaty [2]. Furthermore, the transportation sector is one of the most significant contributors to global greenhouse gas (GHG) emissions, responsible for approximately one-fifth [3]. As such, the rapid industrialization of effective solutions through clean technology innovation is critical to mitigating climate risks.

One promising avenue toward achieving net-zero goals in the transportation sector is the electrification of the automotive industry [4]. However, established companies and emerging players face significant challenges in innovating and competing [5]. Challenges and impediments to innovation are well-known phenomena, vary by company and industry, and are often interdependent. Nevertheless, they are primarily characterized by misaligned incentives and inhibiting company culture [6], insufficiencies in customer

validation [7], high resource demands, especially amplified in capital-heavy industries, and protracted time-to-market periods [8].

In recent decades, companies in the manufacturing sector have encountered a surge in global competition, prompting a need to rethink traditional business strategies [9]. In addition, the COVID-19 pandemic, international conflicts, protectionist policies, and the leveling of emerging markets have all compounded these issues and contributed to regionalization trends that have acted as a counterpoint to the once-dominant narrative of globalization [10]. These macro-level changes have raised questions about supply and value chain distribution and have highlighted the need for secure access to critical resources [11]. Intangible assets have become increasingly dominant in global value chains. As a result, regional factors such as skilled labor, infrastructure, natural resources, and customer proximity have gained newfound importance in companies' localization strategies [12].

To describe this set of phenomena, the portmanteau "Glocalization" has emerged, emphasizing the need for innovation to address commercial, cultural, and technical spheres in a way that aligns with these new paradigms. This shift in focus highlights the importance of context-specific strategies tailored to regional conditions underpinned by a deep understanding of local markets and cultures [13]. This way, companies can adapt to changing global trends and remain competitive in an increasingly complex and uncertain business environment.

The Inflation Reduction Act (IRA), implemented by the United States in August 2022, constitutes a step forward in the trend toward re-shoring value chains. The IRA includes a grant of \$391 billion to support clean energy production, promoting domestic manufacturing and incentivizing companies to invest in cleantech [14]. Notably, several major automotive OEMs and battery manufacturers have announced their plans to establish new facilities in the United States. While this legislation represents a promising initial step in removing barriers to innovation, this paper posits that innovation ecosystems and international innovation networks are fundamental components in ensuring the full realization of substantial financial support. Moreover, successful innovation necessitates an effective transfer of knowledge and know-how. In the long term, the impact of these investments on the market landscape is contingent upon establishing sustainable and continuous improvement processes and the integration dynamics of regional efforts into a global innovation chain, which must be developed in parallel with regional setups.

The recent struggles of Europe to industrialize battery production at a large-scale highlight that the commercialization of key technologies cannot be taken for granted. Despite its traditionally strong background in the industrialization of new technologies and its base of plant and equipment manufacturers, Europe had significant setbacks. Moreover, despite substantial investments and academic strength, the lack of total innovation chain integration has hindered the region's ability to achieve its goals [15]. This paper examines the role of innovation ecosystems in facilitating knowledge transfer and effective industrialization. Furthermore, it explores how innovation ecosystems can help regions effectively use financial resources by guiding knowledge and providing required resources for large-scale endeavors.

Extensive research has focused on the value creation for participants in innovation ecosystems [16] [17]. The concept of innovation ecosystems originated from business ecosystems, wherein firms collaborate to develop customer-centric solutions [18]. The perspective on innovation ecosystems has since expanded and typically refers to a coalition of various stakeholders, their interrelationships, and purposeful collaboration. Numerous regions have independently embraced ecosystem strategies, expanding the potential for promising opportunities and an integrated approach to economic development.

PEM Motion has partnered with local stakeholders in Europe and North America to establish local innovation ecosystems, utilizing its proven four-phased strategic approach. This approach prioritizes the setup of a local innovation ecosystem first. An added global approach to innovation ecosystems is necessary to maximize their potential impact and foster effective knowledge transfer and industrialization. PEM Motion proposes a novel framework, the global ecosystem of local ecosystems, that integrates the strengths of single ecosystems while aligning their efforts on a global level. This approach has the potential to dissolve knowledge silos and foster global cooperation, innovation, and sustainability, meeting the demands of modern, distributed value chains.

2 The Rise of Innovation Ecosystems

2.1 The Key to Rapid Innovation: Understanding the Complex and Interdependent Nature of Innovation Ecosystems

Innovation, "the introduction of new concepts, ideas, or methods [19]," is a multifaceted and dynamic phenomenon encompassing tangible products and intangible entities such as services, processes, and business models. Moreover, innovations, by their very nature, are novel and occur within a complex and interdependent societal context that is often fraught with uncertainty and complexity. Consequently, the innovation process is characterized by conflict, opportunity, and a constant need for adaptation and evolution [20].

Innovation ecosystems have evolved to conceptualize the interdependencies in the innovation process and gained traction in the last two decades. Companies have shifted from a resource-based perspective to a relational perspective to collaborate more effectively [21]. Innovation ecosystems, in turn, provide the structure that allows companies to take advantage of a relational perspective. Nevertheless, the definition of innovation ecosystems and the need for a conceptual approach have been subject to extensive debate among innovation researchers. One of the early researchers in this area, ADNER, conceptualizes innovation ecosystems as "the collaborative arrangements through which firms combine their offerings into a coherent, customer-facing solution [22]." Whereas OH et al. criticize the concept for its potential for false analogies to biology [23], RITALA and ALMPANOPOULOU suggest that it has enhanced innovation research. However, they call for greater rigor in its future use [24]. GRANSTRAND and HOLGERSSON also advocate for the conceptualization and system approach to innovation ecosystems and extend it with complementary and substitute relations. They provide a synthesized definition based on their conceptual review, adding competition, substitutes, and artifacts, highlighting innovation ecosystems' complex and interdependent nature [25].

In conclusion, it is imperative to exercise caution when drawing direct analogies from natural ecosystems to innovation ecosystems. Nonetheless, natural phenomena may suitably explicate certain aspects of innovation ecosystems. In these ecosystems, multiple participants coexist in a symbiotic relationship, subject to shared rules that emerge organically as partners collaborate and thrive sustainably towards mutually agreed targets rather than being imposed by a central authority. Nevertheless, it is common for ecosystems to contain an orchestrator, aligning the actions of the ecosystem participants [26]. Furthermore, small contributors can significantly impact the system's well-being, providing commensurate value to larger partners. Despite competition driving innovation within these ecosystems, it is tempered by cooperation to foster a reasonable and sustainable approach.

The theory of relational rents describes excessive profits that a single firm cannot solely create, whereas only a joint effort and exchange of multiple partners can generate them. DYER and SINGH extensively elaborate upon this theory, which is fundamental to the rationale behind innovation ecosystems, and propose four primary sources contributing to the generation of relational rents: relation-specific assets, knowledge-sharing routines, complementary resources/capabilities, and effective governance. Each source describes a specific interaction that arises through collaboration and leads to improved ecosystem performance [27].

CARAYANNIS and CAMPBELL comprehensively define innovation ecosystems encompassing multi-level, intercultural, and interdisciplinary aspects. This expanded perspective aligns with the vision of PEM Motion to create a global network of interconnected ecosystems. The authors define an innovation ecosystem as a complex system of actors, resources, and institutions that co-evolve and interact within multiple levels, ranging from micro to macro and across disciplinary and cultural boundaries. Such ecosystems facilitate the generation, diffusion, and absorption of knowledge, technology, and innovation and foster the creation of new and sustainable value [28].

PEM Motion envisions innovation ecosystems as a collaborative approach, preferably cooperative, following the relational perspective. The ecosystem entails merging start-ups, industry, academia, investors, policymakers, and regulators in a loop to enable aligned technology development, conforming with internationally renowned innovation research [29]. Thus, multilateral partnerships and flexible cooperation facilitate knowledge transfer and mutual learning within the ecosystem. In summary, partnering companies

benefit from a rapid market response, industrialization, and reduced uncertainty and cost in the innovation process [30].

Innovation ecosystems have garnered significant attention and appreciation due to their numerous advantages. For example, a 2020 study by DELOITTE demonstrates that participating in ecosystems benefits its participants. According to the study, 53% of manufacturers who participated in the survey reported an expansion in their company's innovation capacity. An additional 27% expect to gain these benefits but are not currently involved in any ecosystem. Moreover, 58% of manufacturers in an ecosystem report experiencing a more rapid time-to-market for their products and services [31].

2.2 Study of Success: Thriving Innovation Ecosystems

In recent years, the proliferation of innovation ecosystems across various regions globally has gained significant momentum, particularly in proximity to renowned universities. These ecosystems compete for resources, such as human capital, investment, partners, recognition, and reputation. Notable examples of successful innovation ecosystems include MIT Kendall Square and the Austin Start-up Ecosystem in the U.S., TUM Campus Garching in Europe, and the rapidly emerging Shenzhen ecosystem in China [32]. These ecosystems have attracted widespread attention and are perceived as models for promoting innovation and economic growth.

Aachen, Germany, has been experiencing significant growth in its innovation ecosystem, emerging concurrently with other global efforts. PEM Motion has made a substantial contribution to the foundation and development of the Ramp-up Factory and Electromobility Laboratory (eLab) on the campus of RWTH Aachen. As more entities joined and independent initiatives were launched, the ecosystem grew and developed into several interdisciplinary excellence clusters of highly intertwined entities. The Ramp-up Factory and eLab embrace the Return on Engineering (RoE) approach, which radically altered industrialization. The iterative prototype development process of RoE is focused on engineering and aims to simultaneously reduce the cost and time of industrialization while ensuring high levels of customer satisfaction. Based on this approach, both facilities have demonstrated exceptional capabilities in reducing uncertainty, lowering economic barriers in the innovation process, and de-risking heavy capital expenditures. The infrastructure-as-a-service (IaaS) business model helps companies of all sizes to mitigate high upfront capital expenditures. Established companies can use the IaaS to experiment and tap into new technology fields while eliminating the risk of early investments. Smaller and younger companies can thrive with access to prohibitively expensive machinery and infrastructure. Integrating production engineering-focused partners into this ecosystem accelerates industrialization and provides valuable support to clients. The successful commercialization of the StreetScooter has proven the RoE concepts and introduced novel approaches to vehicle development. KAMPKER et al. outline the concepts and underlying research in their book, "Think Big, Start Small," which aptly summarizes the proposed approach [33].

In the Aachen innovation ecosystem, diverse stakeholders, including academia, research institutions, political bodies, economic development organizations, and industry players, have shared a common regional vision and strategy. As a result, the ecosystem has seen significant infrastructure investment and evolved into a thriving decentralized network of participants. This strategic initiative, which began in the early 2000s, has been bolstered by the coordinated efforts of its stakeholders and has yielded impressive results, as demonstrated by the emergence of numerous tech start-ups and an increase in university-affiliated patent applications in the region [34] [35]. Recognizing these achievements, Aachen has earned the moniker "Engineering Valley of Germany."

2.3 Rethinking Innovation and Value Chains: Balancing Regionalization and Global Integration

Despite the prevalent narrative and perception of globalization, regionalization has received relatively little attention and appreciation recently. O'NEIL rejects the notion that global value chains are solely governed by globalization and highlights that regionalization trends and globalization are not mutually exclusive. The intricacy of modern value chains necessitates a differentiated strategy for setting up value chains. A promising approach involves combining global and local efforts, leading to the fundamental premise that companies can

benefit from their regional embeddedness to prosper in a globally connected and competitive economy [36]. Empirical research supports this hypothesis and offers methodological frameworks for policy advisory.

In 2011, BARNARD and CHAMINADE highlight the need for global innovation networks to address a mismatch between a location's potential and the requirements of a residing company to thrive. However, they caution against solely engaging regionally due to the strong regional ties that innovative companies have formed. This could result in long-term disadvantages regarding competitiveness and innovation capabilities [37]. Building upon this, IERMAKOVA et al. present a theoretical and methodological framework for regional innovation policy in 2021 that recognizes the coexistence of regional and global requirements [38]. MIT Sloan researchers also forecast the emergence of an interconnected ecosystem network supported by robust local initiatives [39].

Political institutions at various levels have increasingly recognized the benefits of fostering a network of interconnected innovation ecosystems. For instance, the European Union has acknowledged the importance of such networks in its innovation strategy and has been actively promoting cooperation among different regions [40]. Similarly, the United Nations has also emphasized the significance of collaboration in innovation ecosystems as a key element of its Sustainable Development Goals. This recognition and support from political institutions demonstrate the growing awareness of the value of innovation ecosystems in driving economic growth and sustainable development at both regional and global levels [41].

3 A Practical Approach to Establishing Innovation Ecosystems

3.1 A Roadmap to Thriving Ecosystems: Innovation Ecosystem Development Adapted to Local Strengths

Following the successful establishment of the Ramp-up Factory and eLab in Aachen, PEM Motion has embarked on a journey towards creating a global network of innovation ecosystems in partnership with local stakeholders and interest groups in Mexico, the U.S., and Canada. As a founding partner, PEM Motion has contributed its expertise in ecosystem development to regional endeavors, leveraging its potential to pursue the vision of an interconnected innovation network. The proposed roadmap and objectives in ecosystem development are universal, while the strategy requires adaptation to local strengths. The four-phased approach breaks down into scoping, feasibility study, planning, and implementation and is characterized by a long-term commitment to the region. It has been formulated based on the successful experience from Aachen and is aimed at realizing the full potential of each location.

For instance, the ecosystem in Aachen is closely aligned with the region's strength in production engineering. In contrast, the ecosystem in Mexico focuses on the automotive supply chain, with particular emphasis on the development of structural components and electronics, alongside workforce development for these sectors. Likewise, Sacramento's ecosystem is dedicated to future EV and EV component manufacturing and emphasizes workforce development. Finally, the ecosystem in Windsor, Canada, focuses on small series production for electric future mobility solutions, complemented by training and qualification.

PEM Motion's efforts extend beyond North America. Complementary expertise and market opportunities have initiated concepts for innovation ecosystems in India, Rwanda, and Costa Rica.

3.2 From Idea to Concept: The Scoping Phase Builds Strong Foundations

Establishing ecosystems requires the collaboration of various stakeholders with diverse backgrounds and interests. The scoping phase marks the starting point for a joint endeavor and highlights partner identification as well as integration. Innovation research provides frameworks for this early phase that support identifying relevant roles and responsibilities. Research-based methods, such as the Innovation Ecosystem Strategy Tool developed by CeRRI at FRAUNHOFER IOA, excel through their openly defined role descriptions, which help avoid narrow thinking and alternative-focused partner selection. This approach assesses potential partners holistically and identifies gaps in strategic partner selection. These approaches organize ecosystem relations by connecting input and output relations between roles and enable a more comprehensive and coherent approach to ecosystem development [42].

Visits to different sites and alignment meetings are also crucial in creating a shared vision and understanding of the endeavor. In this regard, project management provides detailed deliverables and an exact time plan during the scoping phase, which all partners agree on. Therefore, effective project management is essential to ensure that the scoping phase proceeds smoothly and that all parties are aligned on the goals and expectations of the ecosystem development process.

The scoping phase is a critical first step in establishing innovation ecosystems. Research-based methods help to avoid narrow thinking and ensure a more comprehensive approach to partner selection. Visits to different sites and alignment meetings are also essential in creating a shared vision and understanding of the endeavor. Finally, effective project management is key to ensuring that the scoping phase proceeds smoothly and that all parties are clear on the goals and expectations of the ecosystem development process.

3.3 Highlighting Regional Potential: Tailored Feasibility Study Critical for Success

The subsequent feasibility study ensures the success of an innovation ecosystem by validating the funding structure, deliverables, and partner overview. Establishing an innovation ecosystem requires a tailored strategic approach for each region, considering its unique heritage and preconditions. While the framework has been successfully implemented in multiple locations, it must be adapted to each region's specific strengths and requirements. The feasibility study is crucial in this process, providing a comprehensive understanding of the region's potential and challenges. Thus, ensuring that the strategic approach is tailored to the region's unique desires and strengths. The adaptive framework leverages the region's distinctive resources and capabilities to promote a sustainable and thriving environment for innovation and growth.

Focusing on a region's strengths is deliberate because it balances insufficiencies out. Research supports this approach by demonstrating that regions with a low level of industrialization can compensate for innovation through highly specialized research [43]. Thus, the feasibility study aims to assess the existing resources and capabilities of the region and identify areas where improvements are necessary. In addition, the study evaluates the compatibility of the ecosystem partners' goals and objectives to ensure that they align with the overarching vision of the innovation ecosystem.

The analysis of the industrial structure offers insight into the nature of innovation already taking place within the region. Factors such as the presence of a robust original equipment manufacturer (OEM) with extensive research and development capabilities, a collection of strong small and medium-sized enterprises (SMEs) with profound technological expertise, and the emergence of promising start-ups have been identified as significant contributors to innovation. Each entity brings distinct advantages to the innovation process, but their successful integration into a larger innovation ecosystem is essential.

While several success factors and stakeholders exist, parallel action can hinder the pace of innovation. The feasibility study assesses the extent to which existing structures serve as a foundation for establishing a successful ecosystem. It also evaluates the potential integration of key partners and proposes solutions for aligning their competencies with the roles and responsibilities within the ecosystem. Disproportionate or poorly coordinated efforts may create friction that impedes the commercialization of innovation. Therefore, it is imperative to address such imbalances and ensure that stakeholders work in a coordinated fashion to optimize the intended performance of the innovation ecosystem.

The presence of pre-existing local structures in a region can prove advantageous, as it eliminates the need for an ecosystem to be built from scratch. However, adding or modifying certain roles within these structures may be necessary to fully leverage the region's potential. For instance, a traditional, resource-based supplier network of local SMEs that revolves around an OEM, may lack a framework that facilitates R&D projects with academia. In this scenario, an innovation ecosystem can facilitate a symbiotic relationship and knowledge transfer between SMEs and the local university.

Integrating universities and colleges is a critical aspect of the feasibility study, as they play a pivotal role in creating and transferring knowledge within an innovation ecosystem. Aligning the vision and mission of the ecosystem with the key research areas of local academic institutions is imperative. The nature of research conducted by these institutions is also important for positioning within the innovation chain. Applied and fundamental research contributes to different technology readiness levels and must be carefully considered when integrating universities into the innovation ecosystem. Moreover, the benefits of integrating universities

are amplified when there is pre-existing cooperation between various branches and disciplines, facilitating cross-disciplinary collaboration and promoting a more comprehensive approach to innovation.

Furthermore, we have observed that some universities have already introduced programs to promote entrepreneurship and start-ups, which can be expanded by providing access to ramp-up facilities. High student engagement and entrepreneurial spirit among students present an excellent talent pool for the ecosystem. Moreover, funding new start-ups and relocating the industry in the region can retain talented graduates and attract a highly qualified workforce. In addition to their role in promoting entrepreneurship and start-ups, universities are an essential platform for workforce development.

Furthermore, universities often possess extensive lab equipment for integration into basic research or early prototyping, strengthening the innovation ecosystem. Overall, the involvement of universities and colleges significantly enhances the feasibility and effectiveness of an innovation ecosystem.

The innovation ecosystem approach we propose differs from many existing incubation and acceleration programs by covering the entire spectrum of product commercialization, from conceptualization to prototyping and series production. We have found that the transition from prototype validation to commercialization can be particularly challenging. Therefore, a holistic approach is necessary to effectively pull the right resources at the respective technology readiness level. In addition, the feedback loops between academia, start-ups, and other stakeholders are critical for technology validation and project alignment.

For effective requirements management, external impediments and roadblocks must also be considered when evaluating the feasibility of an ecosystem in a designated region. For example, the regional analysis must include an assessment of local laws and regulations that may inhibit the endeavor. Additionally, any impediments caused by the existing manufacturing landscape, high manufacturing costs, or a lack of a qualified workforce must be identified. Considering these factors, the implementation strategy is based on a comprehensive analysis of the opportunities and challenges that may arise while implementing an intentional ecosystem.

The feasibility study recognizes the significance of logistics and its impact on the successful establishment of an innovation ecosystem. Based on PEM Motion's experience in setting up e-mobility manufacturing facilities, several considerations have been identified that require early attention during the planning phase. While the following aspects are not exhaustive, they are particularly salient. First, the logistics involved in managing prototype batteries, testing facilities, and related equipment pose significant complexity that needs to be carefully addressed at the outset. Second, work efficiency and manufacturing productivity decrease with increasing physical distance between facilities. Third, the feasibility study must evaluate how facilities for hardware development can be centralized to minimize transportation and improve efficiency. Anticipating these factors early in the feasibility study mitigates the risk of encountering negative surprises during the planning or implementation phase, thereby ensuring the innovation ecosystem's smooth and successful realization.

Identifying customer needs within an innovation ecosystem is a multifaceted undertaking requiring attention to multiple perspectives. On the one hand, it is necessary to consider the needs of the ecosystem's customers and the individuals or entities to which the business model is targeted. On the other hand, the overall strategy and partner composition must align with the needs of the local end-consumers. The preferences of local end customers dictate the dominant form of mobility and reveal suitable providers. A candid dialogue with potential partners is an effective means of identifying their actual impediments to innovation.

The feasibility study culminates with creating a self-sustaining business model and structure, which sets up the ecosystem's long-term success. Identification of key partners and their roles is paramount in this process. The business model is heavily influenced by the existing preconditions, and as such, the ecosystem's initial offerings will be defined by these conditions. While the ultimate vision may be expansive, focusing on a limited set of offerings with key partners is essential for gaining traction. The objective at this stage is to achieve an easy implementation and a rapid realization of positive cash flows. Upon achieving initial successes, the business model can be refined, and new value propositions added to the network. The feasibility study must also consider future funding sources, such as public grants and potential investors, to enable scaling up the business model. In addition, an innovation ecosystem's governance and stakeholder management can take various legal forms, and the feasibility study thoroughly analyzes these options. Finally,

the study outlines the roles and responsibilities of the leading and supporting entities and the decision-making processes that will be implemented.

To ensure successful ecosystem development, the feasibility study must assess logistics, customer needs, and partner composition. Based on the outcomes of the feasibility study, the decision to advance the ecosystem project is made. This decision point is of utmost importance, as it signals to stakeholders the potential of the region to foster innovation. Once the project sponsors give the green light, an extensive planning phase follows, translating the strategic vision into actionable plans and initiatives. This planning phase is a critical component of the project, as it sets the foundation for the successful implementation and scaling of the ecosystem.

3.4 Designing a Sustainable Business Model: The Crucial Role of Investment and Operational Planning

Two interconnected considerations primarily govern the planning phase: detailed investment and operational ramp-up planning. Detailed investment planning is grounded in a shared internal understanding of the overarching strategic objectives, critical for resource prioritization. Given innovation's elevated priority, investments must align with measures that enable the rapid realization of tangible innovative outputs. This requires a comprehensive analysis of various investment scenarios that account for the inherent uncertainty in innovation management. The suitability of the investment scenarios hinges on their alignment with the operational ramp-up plan, which must be closely monitored throughout the planning phase to ensure effective implementation. The fundamental principle guiding operational ramp-up planning is to commence with a modest scale of operations while anticipating realizing a more expansive vision. In this regard, the planning process expands upon the assessment conducted during the feasibility study to explore possibilities for extension and centralization. Employing the RoE approach, an iterative plan is devised to facilitate the expeditious deployment of the envisioned technical operations. However, alternatives to an iterative plan do not provide sufficient feedback and are typically fraught with considerable risks and high capital expenditures. Therefore, an iterative plan that accounts for uncertainties is preferable to optimize operational efficiency and minimize risk.

To effectively plan for business development, it is imperative to integrate potential clients and stakeholders at the earliest stages of the planning process to address their specific requirements. Although this integration affords a comprehensive understanding of a broad spectrum of expectations and needs, the initial operations must remain focused and tightly managed. Over time, the ecosystem of stakeholders and partners gradually expands its capabilities to meet the evolving needs of the business. Economic developers and universities, as strategic partners, contribute to this process by conceptualizing and proposing teaching and qualification programs and research concepts during the planning phase.

These collaborative efforts ensure the effective integration of stakeholder needs, optimizing the business development planning process.

3.5 From Planning to Reality: Prioritizing Tangible Outcomes in the Implementation Phase

In the implementation phase, the ecosystem matures from concept into reality. At this stage, the initial products and services can be offered through early members of the ecosystem. Service providers involved in the feasibility study and planning have an advantage during implementation due to their familiarity with the plans and ability to provide detailed input. PEM Motion is involved with the previous stages and can immediately contribute engineering support and expertise due to the collaboration environment fostered during the initial phases of the ecosystem's development. Other early contributors also participate in the initial offerings due to their participation in the design of the ecosystem.

During the launch of a new ecosystem, external factors may require strategic pivots that require plan changes. The multi-phased deployment model adopted by PEM Motion remains agile and adaptive, accommodating new technologies and developments within the market. In addition, diligent scenario planning provides the flexibility to address contingencies during the implementation phase while remaining aligned with the overarching strategic objectives. As a result, PEM Motion can proactively navigate the complexities of

technology development and implementation, optimizing its resources and capabilities to achieve the desired outcomes.

Project management is a critical linchpin across several organizations, collaborating closely with construction companies and other stakeholders to ensure successful project delivery. Previous projects have demonstrated the importance of showcasing success and the value created, even at the smallest scale, to gain traction and secure stakeholder buy-in. The first project is a crucial benchmark, providing insights into network dynamics and informing the alignment of future projects and investments. As such, it is incumbent upon project managers to expedite the implementation of the first project to establish a foundation for subsequent efforts. Presenting tangible results increases attention and attracts potential clients, bolstering success prospects. By prioritizing tangible outcomes, project management can foster a culture of excellence and optimize project delivery, ensuring client satisfaction and stakeholder approval.

The efforts of PEM Motion are complemented by a comprehensive marketing and sales campaign, which encompasses structured promotional activities such as networking events, symposiums, exhibitions, product launches, and Techathons. These initiatives are reinforced by a collective knowledge management approach, aimed at strengthening the bonds within the ecosystem and expanding engagement, particularly within a relation-based network. By leveraging these strategies, PEM Motion can optimize the ecosystem's outreach reach and influence while internally fostering a culture of collaboration and co-creation. Furthermore, through effective marketing and sales efforts, PEM Motion can raise awareness of its capabilities and value proposition, while cultivating a loyal customer base and enhancing its reputation within the industry.

3.6 Introducing the "Ecosystem of Ecosystems": The Promise of a Global Network of Innovation Ecosystems

The trend toward concurrent globalization and localization inspired the proposal of a global network of innovation ecosystems. Given the research findings, PEM Motion is developing an innovative and forward-thinking business model framework for a global "ecosystem of innovation ecosystems." Drawing inspiration from the St. Gallen Business Model Innovation approach, the framework empowers organizations to participate in a global innovation ecosystem network. The St. Gallen methodology fosters ideation by combining existing business models and building upon recurring patterns, enabling companies to generate new ideas and explore novel avenues for growth [44].

PEM Motion's concept of a global framework is rooted in the significance of local strengths and the potential to leverage cultural differences to unlock untapped potential at a larger scale. Leveraging the strengths and knowledge of local ecosystems, companies can create products and services tailored to local markets, leading to increased success and competitiveness. The global "ecosystem of ecosystems" also encourages the exchange of knowledge and resources across regions, while guaranteeing financial and operational independence to protect the objectives of local stakeholders. A network of global innovation ecosystems provides companies with the flexibility and adaptability needed to thrive in a rapidly changing business environment.

The collaborative approach of a global network of innovation ecosystems can accelerate and enable innovation in various fields, including addressing global challenges like climate change. By leveraging different regions' diverse perspectives, knowledge, and resources, a network of innovation ecosystems can develop and implement more effective and sustainable solutions. The network can also facilitate the transfer of technology, expertise, and best practices between regions, reducing duplication of effort and promoting collaboration and common standards. Subsequent effects contribute to a more interconnected and collaborative world focused on solving some of humanity's most pressing challenges.

Through various international initiatives and partnerships, PEM Motion has forged strong relationships between its locations around the world. One frequent practice is to staff industry projects with team members located across the globe to leverage the diverse expertise and know-how of engineers, consultants, and researchers. Overall, a global framework represents a significant step toward building an effective and efficient network of local innovation ecosystems.

4 Embracing the Future: Connecting Innovation Ecosystems Globally for Greater Impact

Industrializing sustainable innovation provides a lever we need to solve urgent global challenges. However, significant impediments have hindered the successful industrialization of innovation in many cases. Friction in the industrialization process causes failure to deploy innovative products rapidly and depletes resources unnecessarily. Although failure is considered a crucial part of innovating, failure caused by friction is undesired and preventable. Efficient innovation ecosystems and the presented Return on Engineering (RoE) approach mitigate friction in the innovation process. These facilitated innovation processes not only generate more commercial opportunities but also promise an advancement of humanity.

This paper highlights innovation ecosystems' opportunities to conceptualize and foster innovation and outlines opportunities to evolve the prevalent concept of local innovation ecosystems by integrating them into a global network.

PEM Motion has successfully demonstrated the value of innovation ecosystems across the globe by partnering with various stakeholders and establishing local innovation hubs. Through its four-phased strategic approach, consisting of scoping, feasibility study, planning, and implementation, PEM Motion has tailored its approach to the strengths and market opportunities of its regions, creating effective and sustainable innovation ecosystems.

The principles guiding innovation ecosystems and the RoE approach are expected to inspire other regions to create their ecosystems, leveraging local strengths and market opportunities to promote collaboration and innovation. By centering local stakeholders' interests and visions, PEM Motion's approach ensures a tailored and practical approach to innovation and economic growth.

Academic institutions are key partners in exploring new forms of industry collaboration. Integration into an ecosystem increases their appeal to students, graduates, and researchers by creating interfaces with innovative companies and thought leaders. Economic developers are also important stakeholders in establishing innovation ecosystems. Partnerships with diverse stakeholder groups catalyze thriving hubs for a strong workforce, relocation of companies, and strength through innovation.

The vision of a global "ecosystem of ecosystems" is unique in its ability to build upon pre-existing ecosystems and integrate them into a network. PEM Motion is pursuing this concept and has introduced the idea at the Electric Vehicle Production Days (EPT) 2021 in Aachen to elevate the strengths of these regional efforts to a global scale. The framework and related business models are in their initial phase and will be co-evolved with the current and subsequent creation of local innovation ecosystems. Therefore, PEM Motion solicits feedback from relevant stakeholders and industry players to validate the approach and jointly evolve the business model.

The suggested global framework serves only as a blueprint. Discussions on globally connecting innovation ecosystems and the coexistence of similar networks are encouraged and invited. Future research must assess how global and regional value chains will be distributed. Understanding regional value chains and global connectedness will help find suitable approaches to connecting innovation ecosystems and strategizing innovation globally.

The next steps involve implementing the necessary structures and pursuing successful projects within the network to establish a self-renewing global ecosystem. PEM Motion actively seeks dialogue with potential partners to expand its ecosystem network.

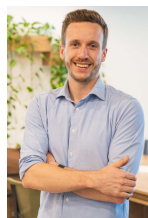
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