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Technological Capabilities to Adopt Open Innovation: A Case Study

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Abstract

Startups are vital for economic growth in Indonesia's technology ecosystem. Open innovation is crucial for them to leverage shared resources and validate product-market fit. Governance of technological innovation is necessary to support national capacity. This study assessed an early startup's capability to adopt open innovation and strategies to enhance innovation capabilities. An instrument was developed to evaluate the startup's readiness for open innovation. Metrics for measuring openness and the impact on technological capabilities were examined. The questionnaire's assessment variables were established and categorized into technological components: technoware, humanware, inforware, and orgaware (T, H, I, O). A survey was conducted on the data was analyzed to determine the company's technological capability using the Technology Contribution Coefficient (TCC) metric to assess its ability to adopt open innovation. We found that the company has the capability to implement open innovation, but improving low-rated subcriteria, especially orgaware, is necessary for better technological capability and reaping the full benefits of open innovation. To improve financial sustainability, partnerships with external institutions for quality resources and collaborating with suppliers, customers, research institutions, or startups can reduce costs and open new market opportunities.

Keywords
Technological Capability, Open Innovation, Early Startup.

1. Introduction

Technological capabilities encompass a nation's capacity to develop, adapt, and apply technology for economic and societal benefits. Improved technological capabilities enable industries to increase productivity, reducing production costs and enhancing competitiveness in global markets (Feng, Sun, Chen, & Gao, 2020; Peerally, De Fuentes, & Figueiredo, 2019). Technological advancements can drive sustainable growth by promoting resource efficiency and environmental responsibility (Omri, 2020).

With its vast population and emerging middle class, Indonesia presents a promising economic development landscape. As a nation that recognizes the potential of its youthful demographics and thriving entrepreneurial spirit, Indonesia has a unique opportunity to harness technology-driven innovation to propel its economy forward [2]. In an era where technology plays a fundamental role in shaping global economies, Indonesia's ability to harness technological capabilities is critical to its future economic success.

Early-stage startups play a pivotal role in Indonesia's technology ecosystem. These young and agile companies often introduce groundbreaking innovations, but their success depends on effective technology commercialization strategies. Startups that commercialize technology effectively can enter the market swiftly, gaining a competitive edge (Sutopo, Astuti, & Suryandari, 2019). Technology commercialization increases the attractiveness of startups to investors, fostering a vibrant startup ecosystem (Civera, Meoli, & Vismara, 2020). Successful startups contribute significantly to economic growth by creating jobs, generating revenue, and raising exports. Technology commercialization fosters entrepreneurship by providing opportunities for startups and small businesses to bring innovative products and services to market (Guerrero & Urbano, 2019). This, in turn, leads to the creation of jobs and the growth of new industries (Zemlickienė & Turskis, 2020).

Technology commercialization is a vital process that bridges the gap between innovation and practical implementation, offering numerous benefits for economic, societal, and technological progress (Chirazi, Wanieck, Fayemi, Zollfrank, & Jacobs, 2019; Kim, Park, Sawng, & Park, 2019). It helps turn ideas into real-world solutions that positively impact individuals, industries, and nations. Technology commercialization can drive economic growth by turning research and development efforts into marketable products and services. This, in turn, creates jobs, stimulates investments, and generates revenue for businesses and governments (Guan & Zhao, 2013; Osawa & Miyazaki, 2006). It encourages innovation by incentivizing researchers and innovators to develop solutions that address real-world problems and meet market demands.

Open innovation, characterized by collaboration with external partners, is vital for early-stage startups in Indonesia. Collaborating with research institutions, industry leaders, and other firms provides startups with access to valuable knowledge and expertise (Scuotto et al., 2020). Open innovation allows startups to leverage shared resources, reducing the cost and risk associated with technology development (Rauter, Globocnik, Perl-Vorbach, & Baumgartner, 2019). Collaborating with partners can help validate product-market fit and accelerate market entry (H. Chesbrough, 2006). Open innovation fosters a robust entrepreneurial ecosystem in Indonesia, attracting global partners and investors (Anshari & Almunawar, 2021; Surya et al., 2021).

Assessing an organization's capability to adopt open innovation is critical for staying competitive in today's fast-paced business environment. Before embarking on an open innovation journey, assessing the organization's capability to adopt this strategy is essential (Waiyawuththanapoom, Isckia, & Danesghar, 2010). This involves evaluating the organization's culture, structure, and processes to determine if they are conducive to open innovation (Cheng, Cheung, Tsui, & Wan, 2018; Valdez-Juárez & Castillo-Vergara, 2021). It also involves identifying potential barriers to adoption and developing a plan to overcome them (Bevis & Cole, 2010b)(Bevis & Cole, 2010a).

To support national capacity, the governance of technological innovation is vital. One of the essential foundations in supporting technological improvements is the evaluation of technology components. Four components of technology, such as technoware, humanware, information, and organization (THIO), can be used as an evaluation basis to assess an organization's capability to adopt innovations, including open innovation (Sharif, 2012). Therefore, by understanding the technological capability for open innovation, organizations can make informed decisions about their innovation strategy and avoid costly mistakes.

This study aims to assess the capability of an organization to adopt open innovation, with an early startup as a case study. This paper also delves into the importance of technology-related capabilities and highlights the significance of

technology commercialization and open innovation within the context of early startup. Based on the assessment result, we identified areas for improvement and developed strategies to enhance the innovation capabilities for open innovation.

2. Literature Review

Lee et al. (Lee, Baek, & Yeon, 2019) described the two types of technological capabilities in terms of two dichotomized aspects: "concept design capability" refers to the ability to develop a concept design, such as blueprints or business models, and "implementation capability" refers to the ability to translate a given format into reality through engineering and manufacturing. They also stressed that once a country achieves a certain degree of affluence, the main form of national technical competence will shift from implementation to design capabilities.

An organization's technological capability is its ability to (a) acquire, use, adapt, and change existing technology, (b) develop new technology, and (c) possess technological knowledge, skills, and processes that are difficult for rival companies to duplicate. Using these ideas as a foundation, we define technical competence as the unique skill that accepts, assimilates, applies, and develops information while conforming to organizational variables. Based on the topics covered, two types of technical competence study exist. One is strategic management research based on the most creative firms in developed nations, concentrating on how firms build their fundamental technological skills (Figueiredo, Cabral, & Silva, 2021).

Technology, according to the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), is the result of a dynamic interplay between various production components. Technical facilities, human capabilities, information, and organization are the four basic components. Thus, technology is the collection of knowledge that manifests itself through the development of products, methods, processes, equipment, and services. Furthermore, engineering is critical in achieving human needs' aspirations and expectations.

Technology consists of four parts, according to the Technology Atlas Team and the Asian Pacific Center for the Transfer of Technology (1989): technoware, humanware, inforware, and orgaware. Figure 1 depicts the framework of technological elements in Technometrics (T, H, I, O). This framework is crucial in developing and establishing a company's competency position.

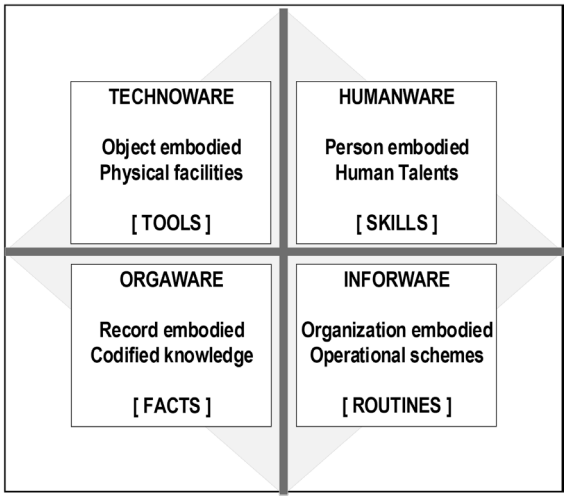

Figure 1. Technology system components (Smith & Sharif, 2007).

A correlation exists between the various components that make up a given system. Specifically, the proper functioning of technoware, which comprises the physical equipment and other material components employed in industrial settings, relies heavily on the performance of humanware. Humanware, consisting of human operators, must operate harmoniously with the technoware components to ensure optimal system performance. The smooth coordination between these two sets of components is facilitated by the adequate flow of information components, which dictates the movement and behavior of both the humanware and technoware. This flow of information components is governed

by the policies and guidelines established by the relevant organizational authorities, as represented by orgaware, which determines the flow of inforware required to support the effective functioning of humanware and technoware.

3. Methods

3.1 Defining the Structural Framework

A questionnaire was developed to gauge companies' readiness to adopt open innovation. The initial phase involved a comprehensive literature review to identify potential open innovation practices and the factors that can impact their adoption. Evaluations for open innovation readiness and metrics to measure the level of openness in a company's innovation process were also reviewed. Additionally, innovation measurement models and the impact of open innovation on a company's technological capabilities were examined. This research established the questionnaire's assessment variables, including criteria and sub-criteria. These criteria were categorized into technological components (T, H, I, and O) to evaluate a company's technological capability in adopting open innovation. Table 1 presents the complete listing of variables employed in the assessment.

Table 1. Development of variables for assessment

Component	Criteria	Sub criteria	Ref	Code
Technoware	Operational flexibility: The capability to adjust and customize operations and technology to meet ever-changing business needs.	Ability to fulfill custom demands/requests	(Puriwat & Tripopsakul, 2021)	T1
		Ability to adjust production/service levels immediately to respond to demand fluctuation	(Puriwat & Tripopsakul, 2021)	T2
	Infrastructure	adequacy of technologies, infrastructure, and facilities	(Aqidawati et al., 2022; Massoud, Fayad, Kamleh, & El-Fadel, 2010)	T3
Humanware	Hiring competent personnel.	Availability of competent human resources	(Aqidawati et al., 2022; Puriwat & Tripopsakul, 2021)	H1
		Training programs frequency	(Al-Ashaab, Flores, Doultsinou, & Magyar, 2011; Aqidawati et al., 2022; H. Chesbrough, 2004; De Wit, Dankbaar, & Vissers, 2007; Michelino, Lamberti, Cammarano, & Caputo, 2015; Petroni, Venturini, & Verbano, 2012)	H2
		Newly hired engineers and scientists		H3
		Count of R&D personnel	(Mirzapour Al-e-Hashema, Soleimani, & Sazvar, 2018)	H4
Inforware	Absorptive capacity: The capability to obtain, share, and apply internal and external knowledge.	Routinely explore for relevant information related to the industry	(Puriwat & Tripopsakul, 2021)	I1
		Information can be shared rapidly within the organization	(Puriwat & Tripopsakul, 2021)	I2
		Evaluate technology regularly and adapt to new knowledge	(Puriwat & Tripopsakul, 2021)	I3
	Understanding customers: The capability to promptly recognize and react to customer-driven opportunities.	Utilize big data to understand customer needs	(Puriwat & Tripopsakul, 2021)	I4
		Communication level with customers to gather insights and ideas for innovation	(Mirzapour Al-e-Hashema et al., 2018; Puriwat & Tripopsakul, 2021)	I5
	Sources of knowledge	Utilizing external sources of knowledge	(H. Chesbrough & Crowther, 2006; Ebersberger, Bloch, Herstad, & Van De Velde, 2012; Köhler, Sofka, & Grimpe, 2012; Michelino et al., 2015; Salge, Bohné, Farchi, & Piening, 2012; Schweitzer, Gassmann, & Gaubinger, 2011)	I6
		Intensity of collaboration		I7
	Intellectual property and rights (IPR)	Number of IP categories	(Al-Ashaab et al., 2011; H. W. Chesbrough, 2016; Ebersberger et al.,	I8
		Number of patents		I9

Component	Criteria	Sub criteria	Ref	Code
		Dissemination of innovation products	2012; Michelino et al., 2015; Mirzapour Al-e-Hashema et al., 2018; Simard & West, 2006)	I10
Orgaware	Financial capability: The capacity to carry out innovative projects with the support of financial and economic resources.	Sufficient financial resources for innovation projects	(Aqidawati et al., 2022; Mirzapour Al-e-Hashema et al., 2018)	O1
	Partnership: The ability to utilize stakeholders' assets, knowledge, and competencies to conduct open innovation practices	Joint projects with other corporations	(Mirzapour Al-e-Hashema et al., 2018)	O2
		Participation of other companies in the innovation process	(Michelino et al., 2015; Petroni et al., 2012)	O3
		Contracting a technology consultant		O4
		Contracts for research with universities and other research institutions		O5
	Market	Degree of commercialization of innovations	(Michelino et al., 2015)	O6

3.2 Assessment Framework

The startup studied in this paper is a technology innovation company focusing on integrating smart IoT, Artificial Intelligence, and renewable energy in Aquaculture. The company develop an eco-friendly aerator with solar PV integrated with smart energy and smart IoT Pond Monitoring and Controlling System to increase the productivity of pond farmers, meet the needs of farmers from pre, installation, and post harvest and also ensure food security in Indonesia and for building sustainable & advanced aquaculture ecosystem.

We developed a measurement instrument to evaluate the startup's performance. One startup was considered as a case study in this paper which operates in the renewable energy and aquaculture sector. We conducted an in-depth interview with the CEO to carry out this assessment. We asked them to score each subcriteria using an interval scale of 1-5, which represents "low," "medium," "high," "top," and "ideal." This scoring system was based on previous research by Sharif (Sharif, 2012) and Aqidawati et al. (Aqidawati et al., 2022) to measure technological sophistication and readiness for new standards. We then analyzed the data to determine the startup's capability level for each technology component. We calculated the technology contribution coefficient (TCC) value, which indicates the company's technological capability to adopt open innovation. In addition, we assessed the capabilities of technoware, humanware, inforware, and orgaware. We recommended open innovation practices that could help the company become more sustainable and contribute to Indonesia's renewable energy sector.

3.3 Determining Technological Capability

This study measured a company's technological capability using the Technology Contribution Coefficient (TCC) metric to assess its ability to adopt open innovation. TCC considers the contribution of each technology component to a system, as well as the intensity of that contribution. Essentially, TCC shows how technology contributes to turning inputs into outputs. Using the values of $T, H, I, O, \beta_T, \beta_H, \beta_I,$ and β_O, TCC were calculated using the equation (Aqidawati et al., 2022; Nugraheni, Hisjam, & Sutopo, 2018):

$$TCC = \alpha \times T^{\beta_T} \times H^{\beta_H} \times I^{\beta_I} \times O^{\beta_O} \quad \text{..... (1)}$$

Where:
α = The technological trend factor
T = contribution value of technoware
β_T = intensity value of technoware contribution
H = contribution value of humanware
β_H = intensity value of humanware contribution
I = contribution value of inforware
β_I = intensity value of inforware contribution

O = contribution value of orgaware
β_O = intensity value of orgaware contribution

4. Results and Discussion

4.1 Technological capability

Upon thoroughly reviewing the questionnaire, we have gathered pertinent data regarding the capabilities of technoware, humanware, inforware, and orgaware components. Using descriptive statistics, we analyzed the collected information to determine the achievement percentage on each capability scale. This analysis identified the variables that met the established criteria and how much they achieved it. This valuable information has served as the foundation of our open innovation recommendation. Table 2 shows the score for each subcriteria.

Table 2. Capability level of each subcriteria

Component	**Technoware**			**Humanware**				**Inforware**										**Orgaware**					
Subcriteria	T1	T2	T3	H1	H2	H3	H4	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	O1	O2	O3	O4	O5	O6
Score	3	3	2	2	2	3	2	2	2	3	2	2	3	3	1	1	3	1	3	1	1	1	3

Furthermore, we calculated the proportion of each scale's capability concerning all subcriteria. To do this, we compared the ratios of subcriteria that scored low, medium, high, etc., with the total number of subcriteria (23 in total). The results showed that 26% of subcriteria scored low, 35% scored medium, and 39% reached high-level capability. However, none of the subcriteria reached the top or ideal level of capability. The proportions for each level of capability are depicted in Figure 2.

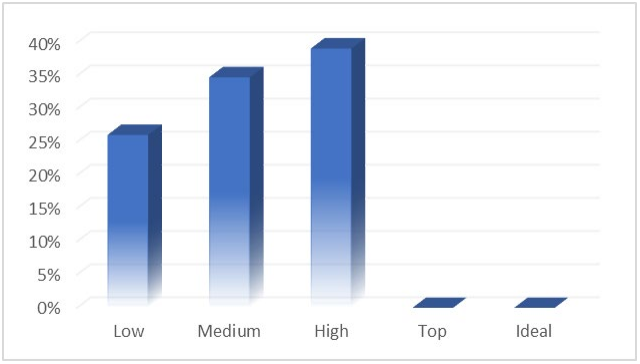

Figure 2. The proportions of capability levels of all subcriteria

We examined each component's contributions toward the overall capability level. This can be achieved by computing the TCC value, which relies on the capability level of each component. Table 2 contains the data needed to establish the capability level of each component. Each component is assigned a range of scores that illustrates the upper and lower limits of variability in conditions. To account for this variability, the average score for each component is utilized as the contribution value. Table 3 presents the results for the contribution value of each component.

Table 3. Contribution value of each technological component

Component	**Contribution score**
Technoware	2.7
Humanware	2.3
Inforware	2.2
Orgaware	1.7

The Total Contribution Score (TCC) was computed using Formula (1) with the contribution score from Table 3 as input. The intensity values $\beta_T, \beta_H, \beta_I$, and β_O, which served as a weight for each technological component, was obtained through the Analytic Hierarchy Process (AHP), which involved pairwise comparison by experts in renewable energy, sustainability, environment, and technology commercialization. The TCC calculation yielded a value of 0.4, and the contribution values for technoware, humanware, inforware, and orgaware are presented in the radar diagram depicted in Figure 3.

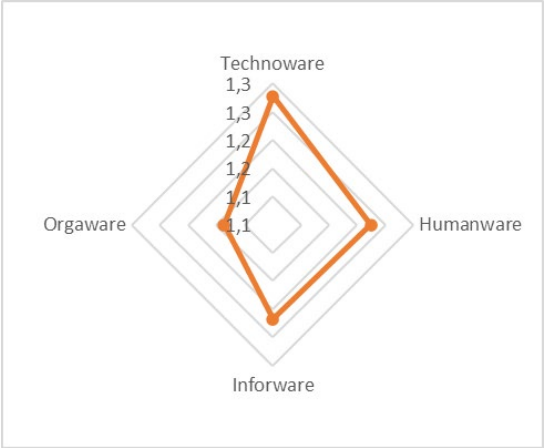

Figure 3. Radar diagram of THIO based on TCC.

The TCC value falls within the standard/reasonably good level of technological sophistication according to the experts' recommended classification of technological sophistication (Rumanti & Hadisurya, 2017; Wiratmaja & Ma'ruf, 2004), as it lies within the interval of $0.3 < TCC \leq 0.5$. Thus, the company has the capability to implement open innovation. However, improving the subcriteria with a low rating, especially the orgaware criteria, is necessary to enhance the organization's technological capability further. By doing so, the organization can fully reap the benefits of open innovation.

5.2 Technoware capability

The company's operational flexibility and infrastructure adequacy were evaluated to determine the technoware capabilities. Based on the operational flexibility criteria, the company exhibited a high level of adaptability and customization in its operations and technology to meet its customers' specific demands and requests. The company's customer base includes farmers and companies within the energy sector. For farmers, the company provided aeration monitoring services and equipment with customizable sizes that could be adjusted to their electricity requirements. On the other hand, external firms could request innovative products in prototype form, and the company would provide custom solutions and even assist with the technology's implementation. The company also accepted mass production orders for technology products, and vendor assistance was available to supplement limited production capacity. The potential for the company to engage in open innovation is significant due to its willingness to collaborate with external companies to develop innovative products.

In addition, the company demonstrated its ability to promptly adjust its production and service levels in response to fluctuations in demand. Despite encountering occasional obstacles, such as vendor-related issues, the company effectively overcame them by utilizing overtime staff or seeking alternate vendors, ensuring timely product availability.

The company's existing technologies, infrastructure, and facilities were insufficient from the infrastructure perspective. While the company could conduct its operations using the current resources and facilities, there was a pressing need for improvement. Specifically, the company continued to rely on substandard materials and equipment for tool calibration and product assembly, which ultimately affected the quality of the products.

5.3 Humanware capability

The level of humanware capability within the organization was measured by assessing the human resources' competency and the intensity of the training programs available for personnel. Staff recruitment was done bi-annually, with hundreds of candidates registering each time. However, due to financial limitations, only 15-20 individuals could be accepted, with up to 5 new hires allocated to each division. As a result, the company's capacity determined the maximum number of engineers that could be recruited.

The development of technological innovation products was carried out by an internal R&D team consisting of 5 individuals. However, given that all members were part-time college students, this number was insufficient to handle tasks such as acquiring custom requests from customers, thereby hindering the company's potential to accelerate product commercialization.

The personnel within the company possessed good technical and soft skills that were well-suited to their job descriptions. However, their competency was not yet high, as the staff recruited for part-time and internship positions were students. To address this, the company provided opportunities for the team to participate in internal and external training programs and mentoring sessions.

5.4 Inforware capability

The measurement of Inforware capability was based on four criteria: absorptive capacity, understanding of customers, sources of knowledge, and intellectual property rights (IPR). Absorptive capacity pertains to the frequency with which a company explores relevant information that can be utilized as a source of knowledge for innovation. The company had a bi-weekly schedule for updating and sharing information among staff members, although this has not been executed consistently. The information gathered consists of up-to-date developments in innovation and technology in aquaculture, market trends and opportunities, and market strategies. Online sources such as websites, research papers, social media, and offline sources, including workshops, seminars, and customers, are the primary sources of information. The company utilized an online platform for file storage and sharing, data management, and collaboration to ensure rapid information sharing within the organization. However, monitoring information and data was inconsistent, leading to occasional information gaps.

The company regularly evaluated technology every two weeks and facilitated the transfer of new knowledge within the organization. This evaluation covered product features and obstacles in the field, enabling the company to develop a roadmap for additional features and plans for derivative products. However, standard documentation has not been appropriately executed, as the CEO primarily handled evaluations. This could challenge company information management, ultimately affecting open innovation practices.

To comprehend customer needs, the company utilized various media, including direct communication through interviews and field observations and indirect communication through telephone calls and texts. Such capability is critical in responding to customer opportunities, such as product enhancements, new technological innovations, or collaboration.

The company's officially registered IPR was a brand at the time. However, one patent is under review, and the company is preparing drafts for two other patents. This may be attributed to the start-up's recent establishment last year, which necessitated the patent registration process. The company continues disseminating its innovative products through exhibitions for promotion and commercialization.

5.5 Orgaware capability

The evaluation of orgaware capability was conducted based on its financial, partnership, and market aspects. In terms of financial ability, the company's capacity to execute innovative projects while being supported by financial and economic resources was scrutinized. The results indicated that, during that period, the company faced a shortage of funds, which consequently led to various obstacles and difficulties that negatively impacted its operations and management. Specifically, the company was compelled to utilize low-cost materials and equipment, affecting product quality. Additionally, the limited funds made recruiting competent and dedicated human resources challenging, consequently causing the company to miss out on opportunities to expand its innovation projects and commercialize its technology. While the company had developed budget plans for several projects, the insufficient funds led it to seek external funding sources, reschedule or delay project completion, or adjust the allocation of funds.

In terms of partnership, the company demonstrated a willingness to engage in external collaboration and cooperation opportunities. At the time, the company had established three collaboration partnerships, each with a unique innovation project. These joint projects primarily focused on corporate social responsibility (CSR), technology development, and events. Despite this openness to partnership and collaboration opportunities, the company remained dominant in project work and dedicated more resources to external company innovation. However, the company had yet to involve other firms in the research and development for its internal creation, nor had it contracted consultants for technology scouting. Additionally, the company had overlooked the prospect of establishing research contracts with universities or other research centers to assist R&D activities within the company.

From a market perspective, the organization has taken steps towards commercializing its products, achieving a Technology Readiness Level of 8 without an official product launch. As a result, the product has not yet gained widespread recognition nor seen significant usage, and its success as a new product remains uncertain. Furthermore, the company's business success cannot be definitively assessed as it has only recently completed the research phase in its early years.

5.6 Proposed Improvements

The company is currently facing financial constraints, leading to a scarcity of resources, including labor, materials, and equipment. To overcome this, the company should maximize its partnership capability by forming alliances with firms and external institutions to acquire high-quality raw materials and equipment used as input for the company's innovation product. In addition, collaboration with more external partners, such as research institutions, customers, startups, or suppliers, can facilitate cost-sharing, risk-sharing, and resource-sharing, enabling the company to undertake ambitious projects or explore new market opportunities that may have been too challenging to pursue alone. Therefore, by opening new market opportunities, it has the potential to accelerate product commercialization.

Furthermore, to improve the financial sustainability, the company is encouraged to maximize its absorptive capacity to effectively utilize external knowledge to enhance its performance. Integrating internal and external capacity is essential to adapt to changing environments quickly. The direct involvement of other potential partners, such as universities, research institutions, or customers, may help the company to overcome market failures and acquire specialized knowledge for innovation endeavors.

Incorporating open innovation into a company's innovation process involves actively seeking customer feedback and ideas. This approach creates products and services catering to their specific needs, increasing customer satisfaction and loyalty. By gathering diverse perspectives and market insights, the company would be better equipped to develop products that truly resonate with its target market. Engaging customers in the innovation process would ultimately lead to improved outcomes and tremendous success for the company.

6. Conclusion

We conducted a case study in an early startup to assess the capability of an organization to adopt open innovation. An instrument was developed, and we analyzed the capabilities of the company based on four components: technoware, humanware, inforware, and orgaware (T, H, I, O). Areas for improvement were identified and we found that the company has the capability to implement open innovation, but improving low-rated subcriteria, especially orgaware, is necessary for better technological capability and reaping the full benefits of open innovation.

Further research can be conducted to explore the specific benefits and challenges of open innovation for companies facing financial constraints. Case studies can be conducted to examine successful partnerships and collaborations in various industries and their impact on product commercialization and financial sustainability. Additionally, surveys and interviews can be conducted to gather insights from customers and external partners on their experiences with open innovation and its impact on their relationship with the company. This research can provide valuable insights for companies looking to implement open innovation strategies to overcome financial constraints and enhance their innovation processes.

This paper can serve as a valuable addition to the existing literature on open innovation, and potentially contribute to the advancement of sustainable development goals. Open innovation with technology capabilities can contribute to industry, innovation, and infrastructure (SDG 9), which seeks to build resilient infrastructure, promote sustainable industrialization, and foster innovation. The process of industrialization lays the groundwork for the necessary

physical systems and structures to function in a society or startup. It also helps to reduce economic poverty by creating job opportunities. Innovation plays a significant role in advancing the technological capabilities of industrial sectors and encourages the development of new skills. The main contributor to income generation and the enhancement of living standards for everyone is inclusive and sustainable industrial development. Additionally, it offers the necessary technological solutions for eco-friendly industrialization.

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