

Technopreneurship and Innovation System for Commercializing OpenWrt Router with Global System for Mobile Communication (GSM) Internet: A Case Study

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Abstract

The Covid-19 pandemic makes people aware of having to work from anywhere so that the need for internet increases and the costs incurred for internet each month increased too. Because of this, several kinds of solutions to answer this problem become interesting. There is a need for technology so that the internet covers all areas at affordable prices. One of the solutions developed is to use an OpenWrt router with internet sources from the Global System for Mobile Communication (GSM) network. This study aims to determine the implementation of technopreneurship and innovation in the development of OpenWrt router from Set Top Box (STB) with a GSM network as its internet source. The data used in this study were secondary data obtained from the internet, and as a tenant, we already start to make a prototype of the product. The analysis is carried out by referring to the technopreneurship approach and innovation systems and implementing the technopreneurship model in the case studies. The result of this research is that technopreneurship and innovation systems are essential for fostering successful technology-based entrepreneurs. The Business Model Canvas (BMC) also helps to develop the commercialization of technological innovations. BMC helped find the keys to product commercialization.

Keywords:

GSM internet, innovation system, router OpenWrt, technopreneurship

1. Introduction

The Covid-19 pandemic has made many changes in our lives. In carrying out face-to-face activities, they have turned into online-based activities to prevent the spread of the virus. Activities turn virtual, such as work from home, online learning, online meetings, shopping, or selling from home through e-commerce platforms. The pandemic thus causes the need for internet access to increase sharply. Not all areas in Indonesia are covered by the Internet Service Provider (ISP) network. In rural areas, internet access is only available via the Global System for Mobile Communication (GSM) internet. If there are 5 GSM internet users in one house with their Subscriber Identification Module (SIM) cards, the cost will be very expensive.

Innovations are needed so that all members can use GSM internet at an affordable cost. One of the innovations in this field is the software-modified Set-top Box (STB) with OpenWRT as a router plus a GSM modem as the internet source. The OpenWrt router software from STB was developed by drg. Fuad Salim (Pulpstone, 2019). The function of this tool is to spread the internet from one GSM sim card so that several devices can use it at once. The router competitor from this product includes TP-Link's 4G Router with the MR6400 model, also a 4G Router from Tenda with a 4G680 model. At the same time, GSM internet operators themselves also have 4G routers such as Telkomsel with Telkomsel Orbit Star 2 Router and XL Operators with XL Home Router MV008.

However, not all innovative technologies can be present in the market. For this innovative product, for example, several challenges must be resolved before entering the market. The challenge is, among others, the legality of the tools and software; the inventor has submitted no copyright to the institution authorized to issue copyright software. Then about the interface of OpenWrt, which is not user-friendly, so inventor must explain the use of each existing feature to the user. There is also about competition with competitors. Because of new products, consumers can choose familiar or well-known products compared to this product even though the price of competitor products is higher.

Previous studies on OpenWrt software, such as research conducted by Iswahyudi and Setiawan (2017), compared the performance and quality of service between the default firmware and OpenWrt firmware TP-Link MR3020 access point. Hidayatullah and Kusnawi (2016) analyzed the quality of service (QoS) original firmware TL-WR841nd with open source-based OpenWrt firmware. Nantoume et al. (2020) developed an inexpensive solution for communication in rural areas with GSM internet sources and using Openwrt based routers. Then Pratomo et al. (2015) examine low-cost OpenWRT-based cellular wireless communication for Voice over IP communication in rural areas. Cahyanto and Nurhuda (2018) researched implementing an OpenWrt-based smart router as a medium for file sharing and chatting.

Previous research on Technopreneurship & Innovation Systems includes research by Linton and Klinton (2019) highlighting how entrepreneurial education methods and approaches with a "through" perspective can be achieved by utilizing design thinking. This point is described conceptually and illustrated with an example. Researchers argue that the method approach to teaching entrepreneurship is beneficial, where design thinking can be one of the valuable tools and approaches to teaching entrepreneurship. Mason and Brown (2014) say that simply creating a supportive framework condition is not enough. Creating a supportive environment for starting a business does not lead to the creation of large companies. The entrepreneurial ecosystem approach is needed as a response to this problem. Thomas et al. (2019) say that the diffusion of digital technologies with their still undefined boundaries announces a new era in entrepreneurship, where traditional ways and forms of pursuing entrepreneurial opportunities will be increasingly reshaped. A new horizon of business opportunities only waits for being discovered and then managed profitably.

It can be seen from several previous studies that there has been no study linking technopreneurship and innovation systems to make OpenWRT router products successful in the market. This study examines the importance of technopreneurship and innovation systems for fostering successful technology-based entrepreneurs, especially for OpenWrt router products. Not all technological innovations can be present in the market. For this reason, it is essential to study management and innovation systems to foster entrepreneurs so that this technology can be successfully present in the market. Research and improvement are needed on technopreneurship and innovation systems to help develop OpenWrt-based router software. This problem will be discussed in this study.

2. Literature Review

2.1. Innovation as a Management Process

Innovation management is complex and risky. The company needs sufficient resources, capable and suitable personnel for proper innovation management to increase innovation capacity. In reality, innovation relates to various knowledge sectors such as the creation of new ideas and concepts, the design and development of models, industrial development, Research & Development, the re-design of a business's process, marketing. Management of technological innovation is one of the challenges faced by management executives today is one of the most demanding to solve. If done correctly, the companies create value and profit, develop sustainable competitiveness, become lively, entertaining workplaces, attracting and preserving the most productive and creative personnel. The management of technological innovation involves all aspects of the company where the development and use of technological innovation enable the company to achieve its targets. It also includes strategic innovation

management, innovation teams and networks, research and development, design and elaboration of new products and services or products. (Carayannis et al. 2015).

The comprehensive research on innovation in organizations has primarily followed a technological imperative, postulating that organizations organize their innovation efforts through research and development (R&D) activities. Theories of innovation are thus shaped mainly from the studies of technology-based innovations in the manufacturing sector, yet are applied in all contexts (Damanpour and Aravind 2012)

While innovation is surprisingly one of the most addressed topics in the practitioner and academic outlets, most research has tended to address innovation as the development of new technology, products, and services. Consequently, technological innovation has dominated innovation research, with related notions such as product development, radical versus incremental innovation, diffusion, and adoption receiving the most attention. However, falling trade barriers, decreasing transaction costs, stagnating developed markets, and overheating emerging markets are forcing firms to look for other areas in which to innovate as a means of gaining and maintaining competitive advantage. This entails a search not only for new products and new technologies but also for changes in the nature of management within the firm, that is, management innovation (Volberda et al. 2013).

Innovation management usually occurs in several recognizable stages. The invention, the main central phase, is preceded by dissatisfaction with the status quo (inside the company) and inspiration from others (usually outside the company). The invention is then followed by a validation process inside and outside the company (Birkinshaw and Mol 2006).

Management breakthroughs can provide a decisive advantage for innovation companies and result in a seismic shift in the industry's leadership. Management innovation can create long-term benefits if it meets one or more of three conditions, namely innovation based on new principles that challenge orthodox management. The second condition is that innovation is systemic and includes various processes and methods. The last condition, innovation, is part of the continuous invention program, in which the development of innovation from time to time (Hamel 2006).

2.2. Innovation Systems

One of the main types of relationships in an innovation system involves transferring or acquiring technology through markets or non-commercial interactions. Innovation is not just an isolated act of learning by a company or other entity; innovation is integrated into a more extensive system that fuels innovation and enables the innovation process to run smoothly. Therefore, the innovation system includes all the main actors and institutions that contribute to creating, developing, diffusion and use of innovation and the interconnection and interaction between all these actors and institutions (Carayannis et al. 2015).

2.3. Introduction to Technological Entrepreneurship

There are clear roles, opportunities, and challenges for entrepreneurs worldwide to accelerate and influence economic growth and take advantage of the Digital Divide through business initiatives in the private sector. Innovations related to moving resources to areas with higher yields. Therefore, knowledge and knowledge-based entrepreneurship will be the primary driver of innovation in the twenty-first century through real/virtual and global/local infrastructure such as a network of incubators. This vision is very promising and attractive in the context of e-Development towards a Knowledge Economy (Carayannis et al. 2015)

2.4. Technopreneurship and Innovation System for Commercializing Technology

Many new technologies are generated from research carried out by universities and R&D centers. However, not all of these technology products can develop in the market. To accelerate the commercialization of technology, both internal and external, technology insourcing is needed. Acceleration of technology commercialization involves providing physical facilities in marketing technology, mentorship and coaching programs, marketing and corporate networking, financial support, and internal regulation itself. In this case, the Technology Transfer Office (TTO) is also involved in introducing incubation technology. The university will also take part as a spin-off, with the TTO in charge of technology incubation (Sutopo et al. 2019).

Several studies discuss the importance of technopreneurship and innovation systems for commercializing technology. Nugrahadi et al. (2020) researched a comparative study of three e-trike products being developed in Indonesia. As a result, the role of TTO and a good ecosystem has a vital role in the success of product innovation in the market. Aqidawati et al. (2020) researched the role of technopreneurship and innovation systems for commercializing battery technology. This paper provides an insight into how technology transfer offices (TTO) organize and manage innovation activities with the technopreneurship model and the constraints of technology commercialization on battery technology innovations. Khofiyah et al. (2020) researched a framework for developing technopreneurship and innovation systems in agricultural drone technology. The results obtained are that management and innovation systems are essential to grow and develop successful technology-based entrepreneurs.

3. Methods

The technopreneurship framework and the innovation system in this study use four frameworks that are combined. The combination of these four frameworks aims to develop a comprehensive system of technopreneurship and innovation. Moreover, from the merging of these four frameworks can be a recommendation in carrying out the process of innovation in other development technologies. This study uses secondary data obtained from research conducted through the internet. Figure 1 explains the technopreneurship and innovation system framework used in this research.

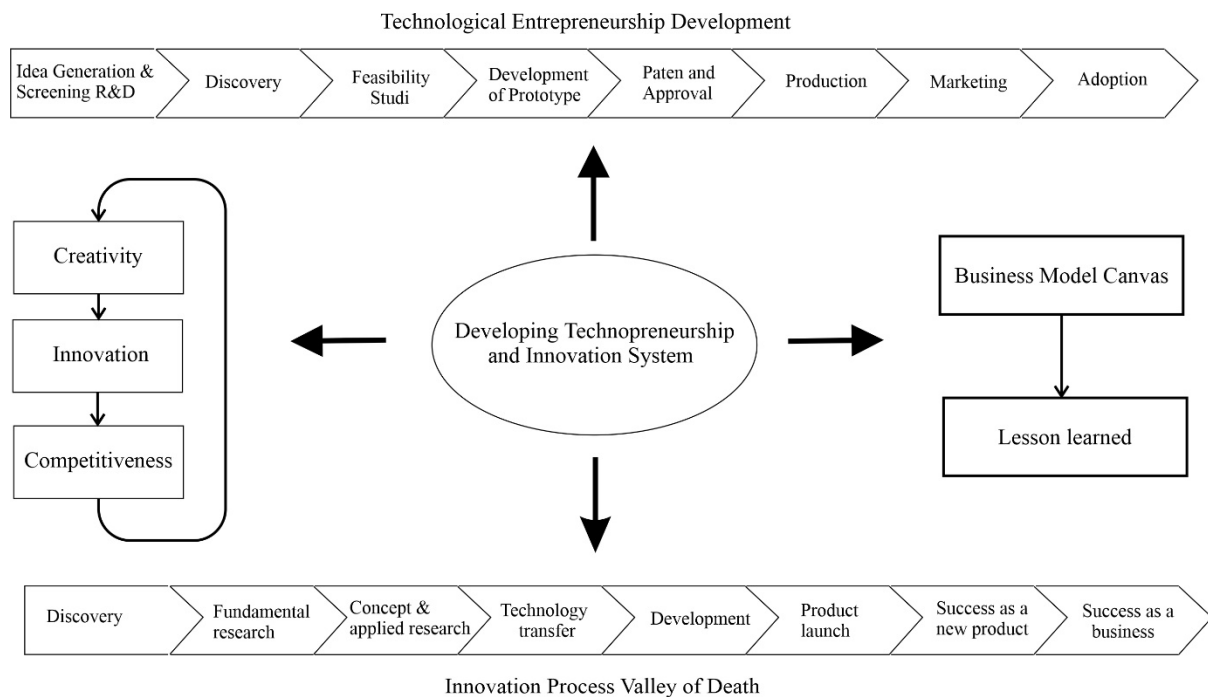


Figure 1. Framework Developing Technopreneurship & Innovation System

Willie et al. (2011) said that there are several roles of technological entrepreneurship in socio-economic development, namely technological entrepreneurship, which is needed to encourage technological innovation to enter the market. Technological entrepreneurship can improve the technological capabilities of a country because technological entrepreneurship will always involve the commercialization of research results, more patents are generated, and patents are a well-known indicator and measure of technological development and industrialization in countries around the world. Technological entrepreneurship is a platform that accelerates the successful diffusion of technological innovation in an economy. The final role is to meet market needs and be a problem solver for the technology entrepreneur to be relevant. Willie et al. (2011) states that there are several stages for Technological Entrepreneurship Development, namely Idea Generation & Screening R&D, Discovery, Feasibility Study, Development of Prototypes, Patenting and Approval, Production, Marketing, and Adoption.

Innovation tends to change the perceptions and the relations at organizational level but its influence is not limited at this level. Innovation in the broader socio-technical, economic and political framework could significantly affect, shape and modify the ways and the means people live, businesses are structured, compete, succeed and fail and nations prosper or decay. Creativity and innovation could lead to competitiveness improvement and ongoing

development. On the other hand, the lack of creativity and innovation is a factor of failed performance and therefore a factor of economic yield failure. In those countries where creativity and innovation are effectively realized, globalization could serve as a drive of beneficial and continuous economic integration (Carayannis et al. 2015).

According to Chirazi et al. (2019), the process innovation stage is an innovation process that is seen based on the BID (Biologically Inspired Design) stages. In this process, innovation consists of 8 stages: Discovery, Fundamentals, Concept and Applied Research, Technology Transfer, Development, Product Launch, Success as a new Product, Success as Business.

The technology-based business incubation (IBT) TTO helps develop technology product businesses using the Business Model Canvas (BMC). BMC is a business strategy that facilitates entrepreneurs to improve their business. BMC was discovered first by Alexander Osterwalder. Then BMC is recognized as a global standard that provides alternative strategies that can be applied to all forms of business models and can be applied to small business businesses categorized as startups (Maharani and Hutabarat 2018).

4. Result and Discussion

4.1. Technological entrepreneurship development

- Idea Generation & Screening R&D

COVID-19 pandemic increased the need for the internet because many workers work from home. Teaching and learning activities are also carried out online, so they require a lot of internet quota. For this reason, internet service providers are needed to accommodate these requests. The need for the internet became a problem in small cities or areas that the wired internet network has not covered. Cable-based internet providers usually have unlimited data package programs. However, installation fees and monthly fees tend to be expensive, and there is a minimum upfront time that is inconvenient for customers because they have to pay upfront. For this reason, an affordable solution is needed for areas that are not yet covered by the Internet Service Provider (ISP) network.

- Discovery

Currently, there is a new alternative as a solution to the above problem by using a modified STB with OpenWRT as a router plus a GSM modem as the internet source. The OpenWrt router software was developed by drg. Fuad. With this tool, the initial cost (the cost of buying a tool) is much cheaper. The monthly fee can be adjusted according to the needs of consumers because it uses a GSM internet provider and can stop at any time if consumers do not want to continue. The disadvantage of this alternative is that the signal quality can depend on the consumer's location, and sometimes it is influenced by the weather.

Figure 2 shows a picture of the products in question from this study. Two types of STB can be changed into an OpenWrt router, namely STB ZTE b860h and STB ZTE hg860p. As for modems, there are various kinds of modems, but it is recommended to use a Hilink type modem.



Figure 2. Pulpstone 4G Router product images (Tokopedia 2021)

- **Feasibility Studi**
Iswahyudi's research (2017) examined the differences between original software and OpenWrt software on the TP-Link MR3020 router and found that the OpenWRT firmware is superior in throughput delay jitter, while the default firmware is superior in the packet loss parameters.
- **Development of Prototype**
Pulpstone developed the OpenWRT software for the OpenWrt 18.06.2-based STB HG680p, which was named Pulpstone OpenWRT 18.06.2. The software and tutorials can be found on the website www.pulpstone.pw. In addition, Pulpstone also develops OpenWRT software for other routers. We can also ask to develop a special OpenWrt software for our router.
- **Paten and Approval**
The thing that can be claimed from this innovation is the copyright of the software development because the hardware used is the STB, and the modem is purchased from products sold in the market. For now, Pulpstone has not tried to claim copyright on the development of this OpenWrt software.
- **Production**
Production can be done by changing the initial STB software in the form of android to be converted into OpenWrt software manually one by one. For those who are experts, it takes less than 30 minutes to do it.
- **Marketing**
For now, Pulpstone has not sold its OpenWrt software development, and anyone can download it for free on the Pulpstone website.
- **Adoption**
In this process, OpenWrt software was further developed according to the wishes of consumers or the market, for example, by adding a file-sharing feature or downloader software.

4.2. Creativity, innovation, competitiveness

The development of this software can increase productivity because the OpenWrt software is superior to the default router software. Due to its affordable price compared to other 4g router products can increase competitiveness in the low-end router market. Other benefits can be obtained from using this tool. This tool can be installed additional software as needed, such as file-sharing software, software to download, or software to monitor CCTV, so it is not just an ordinary router that transmits wifi for the internet.

With the router and internet access, it is hoped that it can increase productivity and work efficiency. With VOIP technology, for example, telephone communication can run without the need for pulses. With video conferencing technology, we can conduct lectures or meetings with various branch offices without meeting face-to-face. Of course, this will be more effective and efficient in terms of time and cost.

4.3. Innovation Process (Valley of Death)

The valley of death is the valley for innovations that have not made it to the market or whose products have not been accepted on the market. The following are the stages of product innovation discussed in comparison with its competitors. Figure 3 shows product competitors of the Pulpstone OpenWRT router, and table 1 shows the stages of innovation in the valley of death of the Pulpstone OpenWRT and its competitors. It can be seen in the table that Pulpstone OpenWRT has not been a success as a new product while its competitors' products have been successful in the market.



Figure 3. Competitor Products Images (Shopee 2021)

Table 1. Stages of innovation in the valley of death

Technology	Discovery	Fundamental research	Concept & applied research	Technology transfer	Development	Product launch	Success as a new product	Success as a business
Pulpstone OpenWRT	v	v	v	v	v	v	-	-
TP-Link MR6400	v	v	v	v	v	v	v	-
Tenda 4G680	v	v	v	v	v	v	v	-
Telkomsel Orbit Star 2	v	v	v	v	v	v	v	-
XL Home Router MV008	v	v	v	v	v	v	v	-

The advantage of the 4G Pulpstone OpenWrt Router is that the price of the products is lower than its competitors, the software can be modified according to consumer needs. In contrast, the disadvantage of these products is its spread range compared to competing products is smaller.

TP-Link MR6400 and Tenda 4G680 are 4G routers issued by router manufacturers, namely TP-Link Technologies Co., Ltd and Shenzhen Tenda Technology Co., Ltd. The advantage of this type of router is that it can be used for all GSM internet operators in Indonesia. The weakness is that the initial setting or initial appearance is sometimes confusing for novice users.

Telkomsel Orbit Star 2 and XL Home Router MV008 are operator bundling routers from Telkomsel and XL. The advantage of router bundling operators is that there is a special package for users who use the router for a lower monthly fee or more quota. The disadvantage is that the router can only be used for the initial operator of the bundling.

4.4. Business Model Canvas

One of the ways the TTO helps commercialize innovative products is by using a Business Model Canvas (BMC). Figure 4 shows a BMC of the 4G Pulpstone OpenWrt router product :

The main partners of the 4G Pulpstone OpenWrt Router are suppliers of raw materials, namely STB and 4g GSM modems and resellers who help sell this product. The key activities undertaken are purchasing raw materials, changing software, quality control, packing and product delivery, and tutorial guidance to consumers. The primary resources for the Pulpstone OpenWrt 4G Router are human resources, OpenWrt development software, tutorials on using products, and production tools in the form of computers and other tools.

The Pulpstone OpenWrt 4G router offers value to its customers in the form of a mobile device, portable, does not require high and an affordable price. Customer Relationships with customers are established through the help of social media and when providing tutorials or guidance when there are problems. Channels are used to reach customers to sell products using online media such as social media and marketplaces. With the help of the marketplace, sales can reach all regions in Indonesia. Customer Segments describes the market targeted by the 4G Pulpstone OpenWrt Router.

The cost structure of the OpenWrt Pulpstone 4G Router is resources and operational costs. The cost of purchasing raw materials is the most significant cost incurred for producing the product. Then there are employee salaries and operational costs, promotional costs for promoting the product. The revenue stream is derived from product sales, software installation services, and revenue from monthly fees for customers whose internet is managed by us.

Key Partners <ul style="list-style-type: none"> • Suplier STB • Suplier Modem 4g GSM • Reseller Products 	Key Activities <ul style="list-style-type: none"> • Purchase of raw materials • Software installation • Quality Control • Packing + Delivery Product • Tutorials to customers Key Resources <ul style="list-style-type: none"> • Human Resources • Software OpenWRT • Product usage tutorial • Production tools (computers, LAN cables, etc.) 	Value Propositions <ul style="list-style-type: none"> • Mobile device (the product is light) • Portable (can be moved) • Does not require high power (can be online 24 hours / day) • Affordable prices both products and monthly cost 	Customer Relationships <ul style="list-style-type: none"> • Promotion through social media • Provide tutorial guides for using the products • Provide assistance if problems occur Channels <ul style="list-style-type: none"> • Online (social media and marketplaces) 	Customer Segments <ul style="list-style-type: none"> • Geographical segmentation: all areas in Indonesia that are not covered by ISP but already have GSM internet • Demographic segmentation: men / women aged 15-60 years • Psychological segmentation: those who like to modify product software, like new technology
Cost Structure <ul style="list-style-type: none"> • Raw material costs • Employee salary costs • Operational costs (electricity) • Promotion costs 		Revenue Streams <ul style="list-style-type: none"> • Income from selling the products • Income from software installation services • Income from monthly fees of customers who entrust their monthly internet subscriptions 		

Figure 4. BMC 4G Pulpstone OpenWrt Router

4.5. Lesson learned

The lesson learned from the results of this study is that management systems and innovation are essential for fostering successful technology-based entrepreneurs. The challenge of developing a GSM internet router can be resolved. For example, for legality issues, we can register a company to sell this tool and register the copyright for the software, then change the user interface so that ordinary users can immediately use it. Furthermore, we can carry out promotions or advertisements for competition in the market so that our products/brands are known in the market.

The Business Model Canvas (BMC) can help develop the commercialization of the 4G Pulpstone OpenWrt Router product. The primary key in the commercialization of this product is the customer relationship and value proposition offered by this product. By maintaining good relations with consumers, whether in terms of promotions, tutorials, or providing assistance when there is a problem, can help instill our brand image in the hearts of consumers. Value propositions such as giving a lower price than competitors make our goods attractive to buy, so many new consumers will be interested in buying this product.

5. Conclusion

A comparative analysis of the development of the GSM internet router has been carried out. This paper provides a study of the appropriate technopreneurship model for technology for these innovative products. The analysis was carried out regarding the technopreneurship approach and the innovation system to understand how the technopreneurship model was applied. Based on the analysis that has been done, management and innovation systems critical to foster entrepreneurs so that technology can be successfully present in the market. Research and improvement on technopreneurship and innovation systems are needed to help develop these innovative products. The Business Model Canvas (BMC) also helps to develop the commercialization of GSM internet routers. BMC helped find the keys to product commercialization. However, not all innovative technologies can be present in the market. There are several challenges must be resolved before entering the market. The challenge is, among others, the legality of the tools and software, the interface which is not user-friendly and then also about competition with competitors. The recommendation from the results of this study is that if we want to be successful in commercializing the GSM internet router technology, the primary key is the customer relationship and value proposition offered by this product. With a customer relationship, it will make our brand known to consumers, while with a value proposition, consumers will be interested in buying this product.

References

- Aqidawati, E. F., Sutopo, W., & Hisjam, M., The role of technopreneurship and innovation system for commercializing battery technology: A comparative analysis in Indonesia. Paper presented at the *Proceedings of the International Conference on Industrial Engineering and Operations Management*, 2020.
- Birkinshaw, J. M., & Mol, M. J., How management innovation happens. *MIT Sloan management review*, 47(4), 81-88, 2006.
- Cahyanto, T. A., & Nurhuda, I. S., Implementasi Smart Router Berbasis OpenWRT Sebagai Media Untuk File Sharing dan Chatting Pada Laboratorium Terpadu Unmuh Jember. <https://doi.org/10.17605/OSF.IO/6QBDW>, 2018.
- Carayannis, E. G., Samara, E. T., & Bakouros, Y. L., *Innovation and entrepreneurship: theory, policy and practice*. Springer, 2015.
- Chirazi, J., Wanieck, K., Fayemi, P. -, Zollfrank, C., & Jacobs, S., What do we learn from good practices of biologically inspired design in innovation? *Applied Sciences (Switzerland)*, 9(4) doi:10.3390/app9040650, 2019.
- Gebauer, H., Exploring the contribution of management innovation to the evolution of dynamic capabilities. *Industrial Marketing Management*, 40(8), 1238-1250, 2011.
- Damanpour, F., & Aravind, D., Managerial innovation: Conceptions, processes, and antecedents. *Management and organization review*, 8(2), 423-454, 2012.
- Hamel, G., The why, what, and how of management innovation. *Harvard business review*, 84(2), 72, 2006.
- Hidayatullah, M. S., & Kusnawi, K., Analisis Perbandingan Quality of Service (Qos) Firmware Original TL-WR841nd dengan Firmware OpenWrt Berbasis Open Source. *Jurnal Ilmiah Teknologi Infomasi Terapan*, 2(2), 2016.

- Iswahyudi, C., & Setiawan, D., Analisis Perbandingan Kinerja dan Kualitas Layanan antara Firmware Default dan Firmware OpenWrt pada Access Point TP-Link Mr3020. *Jurnal Teknologi*, 10(1), 19-25, 2017
- Khofiyah, N. A., Sutopo, W., & Hisjam, M., A framework for developing technopreneurship and innovation system: A comparative study of agricultural drone technology development in indonesia. Paper presented at the *Proceedings of the International Conference on Industrial Engineering and Operations Management*, 2020.
- Linton, G., Klinton, M., University entrepreneurship education: a design thinking approach to learning. *J Innov Entrep* 8, 3 <https://doi.org/10.1186/s13731-018-0098-z>, 2019.
- Maharani, A., & Hutabarat, I. T. R., Case Study On Strategic Development Of Genuine Leather Bags Using Business Canvas Model. In: *International Conference on Industrial Engineering and Operations Management (IEOM) 2018*, Bandung, 2018.
- Mason, C., & Brown, R., Entrepreneurial ecosystems and growth oriented entrepreneurship. *Final report to OECD, Paris*, 30(1), 77-102, 2014.
- Nantoume, A., Degboe, B. M., Niang, B., Kora, A. D., & Ouya, S., Design and deployment of a low-cost communication solution in rural areas: Case of the central region in mali. Paper presented at the *CEUR Workshop Proceedings*, 2647 21-36, 2020.
- Nugrahadi, B., Sutopo, W., & Hisjam, M., Technopreneurship & innovation system: A comparative study analysis for E-trike development in indonesia. Paper presented at the *ACM International Conference Proceeding Series*, doi:10.1145/3429789.3429805, 2020.
- Pratomo, I., Affandi, A., & Rahardjo, D. S., OpenVoice: Low-cost mobile wireless communication project for rural area based on OpenWRT. In *2015 International Seminar on Intelligent Technology and Its Applications (ISITIA)* (pp. 391-396). IEEE, 2015.
- Pulpstone (2019). DOWNLOADS Available at: <https://pulpstone.pw/firmware/> accessed on April 09, 2021.
- Shopee (2021). Hasil pencarian untuk router 4g. Available at: <https://shopee.co.id/search?category=134&keyword=router%204g&subcategory=1343> accessed on April 09, 2021.
- Sutopo, W., Astuti, R. W., & Suryandari, R. T., Accelerating a technology commercialization; with a discussion on the relation between technology transfer efficiency and open innovation. *Journal of Open Innovation: Technology, Market, and Complexity*, 5(4), 95, 2019.
- Thomas, A., Passaro, R., & Quinto, I., Developing entrepreneurship in digital economy: The ecosystem strategy for startups growth. *Strategy and Behaviors in the Digital Economy; Orlando, B., Ed*, 2019.
- Tokopedia (2021). Pulpstone Openwrt di YOYOCOM Available at: <https://www.tokopedia.com/yoyocom/pulpstone-openwrt> accessed on April 09, 2021.
- Volberda, H. W., Van Den Bosch, F. A. J., & Heij, C. V., Management innovation: Management as fertile ground for innovation. *European Management Review*, 10(1), 1-15. doi:10.1111/emre.12007, 2013.
- Willie O, S., Helen O, A., Abiodun A, E., & Maruf, S., Framework for technological entrepreneurship development: key issues and policy directions. *American journal of industrial and business management*, 2011.

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