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Factors and Methodologies in Predicting Take-Up Rate of Internet Broadband Business: A Systematic Review and Analysis

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Abstract: This study was conducted to answer three issues regarding the effort to boost broadband adoption and meet financial feasibility analysis. Kitchenham's systematic review procedure is used to review all of the articles that fulfil the inclusion and exclusion criteria. The results indicate that the Take-Up Rate (TUR), which is defined as the percentage ratio of consumers connected to internet broadband to the total number of available connections, is a significant aspect of the Fiber to The Home (FTTH) internet broadband company, along with Average Rate Per User (ARPU). From the results, it was identified that only seven of the eighteen internal independent factors and twenty-one of the forty external independent factors provided a direct and substantial association with TUR. All of them need to be considered in broadband adoption. This study also found four methods for evaluating TUR: The study discovered four methods for evaluating TUR, that are the influencer-related model, multiple regression, support vector regression, the ideal trajectory of the implemented multi-period FTTH network connection, and the churn approach that may be employed in the remaining years of the FTTH investment. Researchers and practitioners can use the results of this study as a resource while optimizing TUR and building successful FTTH Internet broadband clusters.

Keywords: Take-Up Rate, Internet Broadband, Fiber to The Home, Broadband Adoption, Systematic Review

1. INTRODUCTION

In developing this study perspective, we first took Indonesia as an example. After that, we will take a global view of the focus of this study. The Government of Indonesia created five digital transformation agendas led by the President of Indonesia. One of them is the development of digital infrastructure and the readiness of internet services by deploying the Indonesian digital roadmap. The agenda has continued since the last era, with the program providing nationwide broadband access in non-commercial areas, increasing mobile and fixed broadband in commercial regions, and building infrastructure and connectivity that is secure, reliable, and high-quality [1]. A report released in June 2022 by the Indonesian Internet Service Provider Association (APJII) describes Indonesia's Internet Profile 2022 [2].

In the Indonesia Internet Profile report, the internet penetration level in Indonesia is 77.02%. So, there are 210.03 million internet users out of the 272.68 million people in Indonesia. 77.64% use mobile broadband, 24.36% service fixed broadband, and the rest still use WiFi in public areas. Last year, internet users increased by 3.32%, meaning that most of Indonesia's population used mobile broadband or fixed broadband. Broadband, or the so-called Next Generation Network [3], is a high-speed communication network using a wide bandwidth of frequency (band) that is divided into multiple channels or streams [4]. If it is implemented using the internet, it is called "internet broadband".

Usually, the wide bandwidth of data is transmitted using a high-speed internet connection. Internet broadband speed may vary depending on the technology, media, and service requested [5]. The media used to share broadband services are divided into wireline and wireless. Digital

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subscriber lines, cable modems, fiber optics, and broadband over power lines all use wire as a medium for their subscribers. On the contrary, wireless and satellite technologies use the frequency of radio signals or microwaves to transmit internet services [6]. Downstream speeds are typically faster than upstream speeds for both wireline and wireless Internet delivered to residential customers. They also have maximum (up-to) bandwidth since it is shared with another customer within a cluster area. One method that returns internet broadband service to the customer's endpoint uses fiber optic media. It is known as "Fiber to The X" (location) or FTTX. The endpoint can be a Node (FTTN), Cabinet (FTTC), Building (FTTB), Premises (FTTP), or Home (FTTH). Those methods can be implemented using an Optical Access Network (OAN) that implements active Point-to-Point (P2P) or a Passive Optical Network (PON) that implements Point-to-MultiPoint (P2MP) [7]. Nowadays, PON is more widely used than OAN.

According to Milanovic [8], in PON technology, fiber optic cable is linked from an Optical Line Terminal (OLT) in the operator's equipment, which functions as a broadband service symmetric divider [8], to an Optical Network Terminal (ONT) in the customer's premises [9]. It was chosen for FTTX Internet broadband delivery. The technology is faster to activate new services, gives a broad range of services (e.g., triple play), is easy to upgrade within one activation, increases average revenue per user, reduces capital expenditures to deliver services, and lowers operational spending [9]. The good and efficient impacts of FTTX Internet Broadband Adoption boost the size of economic growth in an area and function as a driver in national development, as mentioned in the strategic plan of the Ministry of Communication and Information of the Republic of Indonesia [1].

As previously stated, implementing FTTH has numerous positive effects on a local, regional, and national scale. From a national perspective, according to Briglauer and Gugler [10], increasing 1% of internet broadband adoption will give a 0.002-0.005% increase in the nation's Gross Domestic Product (GDP). Specifically, FTTX adoption will contribute 0.005% of GDP as the most significant contributor. This study was conducted in European Union countries using a dataset from 2003–2017 of the FTTH Council Europe and EU DAE Dashboard [10]. Another result from Abrardi and Cambini's [11] survey and literature review shows a vast impact on internet broadband adoption around the world using research literature from 2001–2016. They classify it as having macroeconomic, unemployment, and labour market effects [11]. To summarize, internet broadband adoption may have a variety of effects in a region or nation, such as assisting the economy and labour markets to evolve and increasing a country's productivity and GDP in the years ahead.

The impact of broadband adoption is not limited to the nation- or municipality-level areas. This section will mainly show the user's perspective on residential-related areas and how to fulfil them. Martins and Wernick [12] said that most residential users in 2025 will need massively high-quality internet demand due to the application used, the residential user profile, and population structures. Applications that run the internet, home offices, cloud computing, entertainment, video communication, gaming, e-health, e-home facilities, and mobile offloading of data will consume 8–300 Mbps downstream and 8–250 Mbps upstream with less packet loss and latency. It also amplifies research from 2011 conducted by Robert and Charles that most people use internet broadband to connect to school-wide area networks or to learn management systems, play games, and have entertainment [13]. In addition to the research findings, Van der Wee et al. [14] stated that Internet broadband would support residential use, e-business, and e-government. These government initiatives will embrace business activities done in residential settings to reduce paper campaigns in government bureaucracy and promote telecommuting [14]. So, internet service providers must realize high demand from residential areas, which will recognize the purpose of broadband adoption in a nation.

The purposes of broadband adoption by the government and customers have been described in the previous section. This section will describe functionality from an internet service provider's perspective. Internet Service Providers (ISP), or telecommunication operators, contribute as developers and connectors of internet broadband service in an area. In developing the site and considering the facility-and-service-based competition, according to Briglauer and Gugler [15], ISPs will invest in broadband networks, such as in network architecture design, physical infrastructure, services and content, last miles, and end-user terminals. They can invest and act as a single or multi-operator provider [16]. ISP investments must be evaluated using cost-benefit analysis and their value [14]. Another finding from Mohammadreza et al. stated that such assets must be assessed with financial and operational analysis to ensure those initiatives profit to ISP [17]. Therefore, the choice of whether to invest in an ISP or not depends on the number of possible subscribers to the service the number of households in the area, and the average monthly revenue per client during a specific period.

Aside from these two criteria, additional characteristics from the region description and the customer's profile are related to and impact investment decisions. These factors include consumer demographics and profiles, rivals, classification location, age, computer/IT abilities, etc. This article will go through each element identified in the introductory section. We try to select and filter some factors that affect the most potential customers and predict their number. The details will determine the number of subscribers in an area that impacts capital expenditure of area deployment, revenue, operational cost (operations, maintenance, marketing, and acquisition), profit, and loss on financial analysis. Stakeholders will choose the best

areas that have good financial analysis results. Next, management will make a simulation and create a decision for the area that will be developed, create a marketing plan, and conduct a strategic product, pricing, and sales plan in the area.

This paper will provide a systematic review and analysis of the findings of the definition and the factors that affected the number of potential customers of FTTH internet broadband in an area. We will reflect on the prosperous areas that implement good broadband adoption and classify factors from customers and regions. After that, we will find a methodology to predict the sufficient number of potential users to be accounted for in the financial analysis and find relations among the affected factors according to the method.

This paper consists of four parts. The first part of Section 1 is an introduction and initial information regarding FTTH internet broadband. Section 2 will show the research method of this study. Section 3 contains the result, which shows the findings of the review and analysis. The last one is Section 4, which contains conclusions and future implementation.

2. RESEARCH METHODOLOGY

To conduct the systematic review, we adopt the procedure outlined in Kitchenham's study [18]. There are 5 stages that will be conducted in this study as shown in Fig. 1.

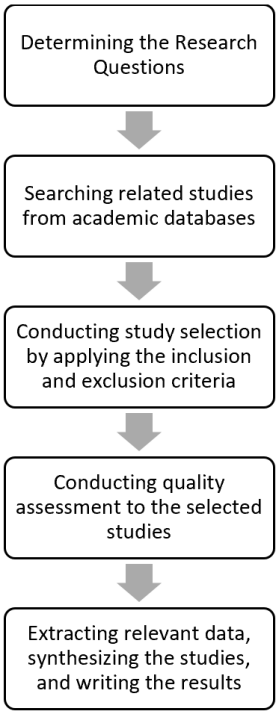

Figure 1. Research methodology.

A. Determining the Research Questions

This systematic review and analysis study has three research objectives. The first is defining the success factor of broadband deployment in a particular area. The next goal is to identify the elements that influenced the success of establishing the FTTX internet broadband area. The final goal is to design a mechanism for forecasting the number of possible customer subscribers based on the affected success element. These objectives will be addressed by three Research Questions (RQs), which are as follows:

1. RQ #1: What is the definition of the success factor (take-up rate) of the development of FTTX/FTTH internet broadband in an area?

   Regarding this Research question, several elaborated results are needed, such as measurement of broadband adoption and the purpose of implementing FTTX Internet Broadband.

2. RQ #2: What factors affected the take-up rate of the development of FTTH internet broadband?

   From RQ #2, we can elaborate more on factors related to increasing the take-up rate of FTTH internet broadband.

3. RQ #3: What are the methodologies to predict the take-up rate in an FTTH internet broadband area?

   This third research question elaborated more on the approach and dataset used during the research.

B. Searching related studies from academic databases

We chose several academic database services as suggested by Brereton et al. [19]. We chose Google Scholar, ScienceDirect, and ProQuest as our searching databases. By using automated search in those three indexing services gives different experiences in forming a query that matches with criteria, research questions, and primary purposes. For example, we stem all keywords from RQ-1 up to RQ-3 and create a basic completed query using " " (double quotation marks) with specific phrases or keywords as depicted below, but the result produced from the Google Scholar index results is 0 findings. Here is the initial query being used in Google Scholar:

> "FTTH take-up" or "FTTH take-up rate" or " FTTH take-up measure" or "FTTH take-up rate measure" or "FTTH take-up factors" or "FTTH take-up rate factors" or "FTTH take-up factors research approach" or "FTTH take-up rate factors research approach" or "FTTH take-up prediction research approach" or "FTTH take-up rate prediction research approach" or " FTTH take-up research method" or "FTTH take-up rate research method" or "FTTH take-up factors research method" or "FTTH take-up rate factors research method" or "FTTH take-up prediction data set" or "FTTH take-up rate

prediction data set" or " FTTH take-up research progress" or "FTTH take-up rate research progress" or " FTTH take-up research issues" or "FTTH take-up rate research issues" or "FTTH take-up factors research issues" or "FTTH take-up rate factors research issues" or " FTTH take-up research impact" or "FTTH take-up rate research impact" or "FTTH take-up factors research impact" or "FTTH take-up rate factors research impact"

Based on the abovementioned experience, we must exclude exact phrases, keywords, or those with the same meaning. We limit the query only to be related to FTTH with specific keywords using " " (double quotation marks) and contain research questions with 1-3 keywords without " " (double quotation marks). This advanced query succeeds in retrieving articles. The query is as follows:

"take-up" "take-up rate" take-up rate measure take-up rate factors take-up rate prediction take-up rate research method take-up rate research issues + FTTH

As we have learned from the Google Scholar indexing service, we created an advanced query for ScienceDirect and ProQuest's indexing services, as depicted in Table 1.

TABLE I. REFINED QUERY IN SCIENCEDIRECT AND PROQUEST

ScienceDirect	ProQuest
take-up rate FTTH + research method + prediction + factors + research issues	(take-up FTTH or take-up rate FTTH) and (measuring take-up or take-up rate factors or predicting take-up or take-up rate research method or take-up rate research issues)

In ScienceDirect, we use the phrase "take-up rate FTTH" to relate queries to the keyword and expand them to research questions containing the keyword or phrase. But in ProQuest, we build the query using the primary word "take-up FTTH or take-up rate FTTH" to filter findings related to it and refocus the result to research question phrases or keywords with () parentheses.

In this stage, we managed to get 192 articles. There are 95 articles from Google Scholar, 48 articles from ScienceDirect, and 49 articles from ProQuest. All of them then will be filtered in the next stage.

C. *Conducting study selection by applying the inclusion and exclusion criteria*

We used several inclusion and exclusion criteria to conduct the study selection process. All findings from indexing services are then filtered with inclusion criteria to have a specific result and comply with the research question. These inclusion criteria are:

1. The article is written in English.
2. The article is in a full paper.
3. The article can be downloaded in full.
4. The article is published in a scientific journal, conference, or proceedings in 2003–2022.
5. There are issues with FTTH take-up or FTTH take-up rate addressed in the article (This is preferable in the telco industry).

Only articles that comply with inclusion and exclusion criteria are followed up to be processed and their information is extracted to answer the research question. In this stage, we managed to get 41 articles. There are 15 articles from Google Scholar, 12 articles from ScienceDirect, and 14 articles from ProQuest.

D. *Conducting quality assessment to the selected studies*

We need to measure each article's quality to prioritize content based on the related research question. We use a checklist of 10 questions in Table 2, as stated by Kitchenham and Charters [20]. Each article will be evaluated for each question and measured by adding 10% if the answer is "yes," 5% if it is "partially," and 0% if it is "no." Articles with less than 70% will not proceed to be reviewed.

TABLE II. ASSESSMENT QUESTION CHECKLIST (ADOPTED FROM [20])

No	Assessment Questions
1	Are the research aims stated clearly?
2	Is the article well designed to achieve these aims?
3	Are the variables considered by the study identified?
4	Is the study discipline stated clearly?
5	Does the study explain the reliability and validity of the measures?
6	Are the data collection methods described adequately?
7	Are they used statistical techniques described adequately?
8	Are the participants' numbers stated clearly?
9	Do the results add to the literature?
10	Does the study add to your knowledge?

By using the assessment question checklist in Table 2, we examined all of the 41 articles and found that all of them passed the 70% threshold, of which 37 of them got 80% and 90% scores. Thus, all articles will be involved in the next stage.

E. *Extracting relevant data, synthesizing the studies, and writing the results*

At this stage, various relevant data are extracted from each article, for example, the author's name, paper title, journal name, topic of the paper, factors discussed in the paper, and also the method used. The data taken is then

used to help the synthesis process for each existing article. The results of the synthesis are then written in an organized and comprehensive manner to answer each RQ. These stages will be described in more detail in the Results and Discussion section.

3. RESULTS AND DISCUSSIONS

A. Articles' demographics

An article that focuses on the general subject of broadband internet was first published in 1987. However, three indexing services' search results led us to the first article that fit the query was published in 2007. Fig. 2 shows the trend over the previous year. The peak was in 2014, and six years later, in 2020, it has resurfaced as many researchers and organizations review, evaluate, and analyze the growth and impact of internet broadband.

Fig. 3 shows that in Google Scholar, from 2007 up to 2022 it was found 15 articles related to query. It has more articles than ProQuest and ScienceDirect results, which are 14 and 12 in the result. Based on Fig. 3, Google Scholar and ProQuest have the same trend in terms of the number of articles related to FTTH internet broadband. They have two peaks in the number of publications in the 2014 and 2019–2021 eras. Meanwhile, ScienceDirect reached its peak in 2019–2021.

B. Answering Research Question #1- What is the definition of the success factor (take-up rate) of the development of FTTX/FTTH internet broadband in an area?

The success factor of internet broadband area development and its relationship to the take-up rate attribute is critical topics of discussion in the first research question. The number of articles associated with RQ#1 is 32, as shown in Table 3. As many as 18 of them come from Google Scholar, 5 from ScienceDirect, and 9 from ProQuest. We revealed in Table 3 that there are 6 topics that related to the answer of the RQ#1.

The number of publications relevant to the definition of FTTH Internet broadband is six articles. Next, there are seven articles describing the global adoption of FTTH, four articles discussing its impact, an article outlining the technique for establishing FTTH Internet broadband, five reports defining the take-up rate, and nine reports assessing financial analysis and its relationship to the take-up rate.

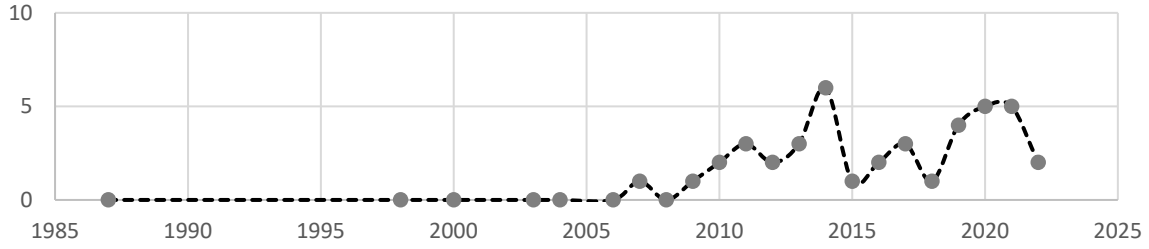

Figure 2. Trend of related internet broadband articles

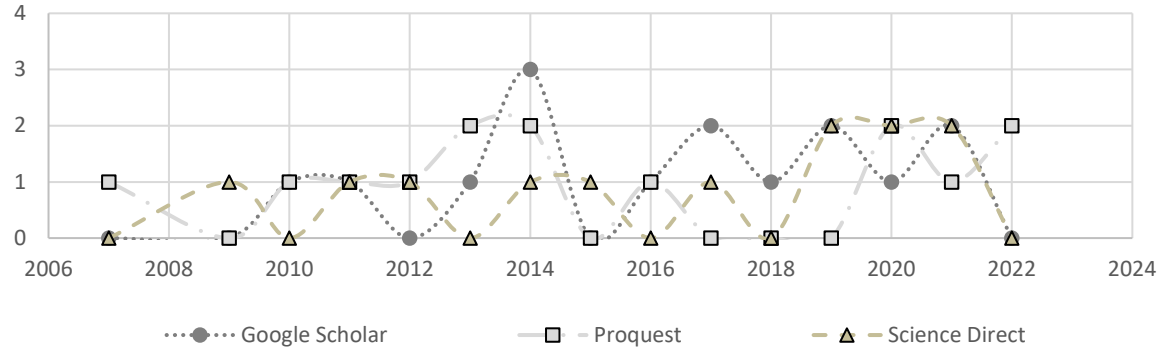

Figure 3. Trend of related internet broadband article per indexing service

FTTH Internet Broadband is a high-speed internet connection that transfers a broad data bandwidth and is offered via a fiber optic media, PON, or OAN-based model, as stated in the Federal Communications Commission (FCC) [5] and in accordance with Izydorek et al. [21]. A node (FTTN), cabinet (FTTC), building (FTTB), premises (FTTP), and home (FTTH) will each get a distribution, as shown by Simatupang [7]. According to Zotkiewicz and Mycek's research [22], the main issue with FTTH implementation is ambiguity. Deployment design, materials, labor expenses, unforeseen real estate investment, and an erratic take-up rate are just a few of the

factors to consider. As a result, while building FTTH internet broadband sites, the take-up rate is crucial, as we discuss in relation to Zotkiewicz and Mycek [22]. Troulos [23] asserts that one of the primary objectives in the FTTH Internet broadband industry, along with ARPU, is the take-up rate or projection model in a region (average rate per user). The take-up rate is critical to providing the service to a newly acquired user in terms of network development expenses, as observed by Troulos [23] and Loskot [24].

TABLE III. RELATED TOPICS TO ANSWER RESEARCH QUESTION #1

No	Topic	Number of related articles		
		Google Scholar	ScienceDirect	ProQuest
1	Definition of FTTH Internet Broadband	2	1	3
2	FTTH Adoption in The World	4	2	1
3	Effect of Adoption and Deployment of FTTH Internet Broadband	2	1	1
4	How to Deploy of FTTH Internet Broadband	1	0	0
5	Definition Take-Up Rate of FTTH Internet Broadband	2	1	2
6	Measurement of Financial Feasibility Studies	7	0	2

The take-up rate, according to Abrardi and Cambini [11], is the proportion of active internet broadband connections to all available connections. The take-up rate is also described by Kwilinsi et al. [25] and Żukowski et al. [26] as the proportion of residential customers who subscribe to the available fixed broadband capacity (coverage). Rosina [27], in agreement with them, proposed that TUR is equivalent to penetration/availability.

Those definitions came from a network design perspective. But, there are also definitions from an operational perspective; Limbach et al. [28] stated that the relationship between customer acquisition and churn rate is constant for the rest of the investment year. This statement reflects that the effort and definition of customer acquisition and churn rate are the same. Therefore, it might be stated that the factors affecting them are the same.

However, the primary constraint today is economic rather than technological. As an essential ratio or percentage, the take-up rate will be used as input for financial and operational feasibility analysis, which will be discussed with the developer, investor, construction service, and network operator, as shown by Asgarirad et al.[17] and Troulos [23]. Several concerns must be addressed, as demonstrated by Charni and Maier [29], including the use of cost-effective communication technologies and the development of reduced TCO infrastructure. As a result, Domingo et al. [30] and Heger and Rohrbeck [31] will assess the cost-benefit model, market potential, cost analysis, revenue, profit margin, expected customer, and willingness to pay. From a design perspective, it is necessary to have an optimistic acquisition scenario in adopting and migrating to recently installed internet broadband service to optimize expensive internet capacity on the supply side and take the take-up rate into account as a deployment strategy [30]. As a consequence, we may control the capital expenditure (capex) of internet bandwidth expenditures by applying the take-up rate value, as found by Zukowski et al. [26], Olender [32], and selecting the lowest capex, as stated by Ahsan et al. [33]. As a result, the network operator will invest carefully.

C. Answering Research Question #2 - What factors affected the take-up rate of the development of FTTH internet broadband?

In this section, we describe factors that affected the take-up rate of the development of FTTH Internet Broadband found in the articles. We revealed that there are two topics that related to the answer of RQ#2 as depicted in Table 4. Regarding dependent and independent factors, Google Scholar gives two articles, ScienceDirect reports 12 papers, and ProQuest provides 11 articles. Then, regarding measuring those factors, only Google Scholar and ScienceDirect present some papers.

TABLE IV. RELATED TOPICS TO ANSWER RESEARCH QUESTION #2

No	Topic	Number of related articles		
		Google Scholar	ScienceDirect	ProQuest
1	What is dependent and independent factor of Take-Up Rate?	2	12	11
2	How to have/measure dependent and independent factor of Take-Up Rate?	1	2	0

The telecommunications provider is responsible for conducting broadband internet activities such as infrastructure deployment, marketing, sales, competition with other provider operators, operations, and maintenance. According to Sharma and Misra's article [34], when implementing public access outlets via network infrastructure or the Internet, two factors must be considered to ensure the telecommunications provider's performance. The first factor comes from the company profile and its services, and the second is delivered from the generic location profile. Therefore, in defining the dependent and independent elements of the take-up rate, we classify independent factors into the internal company and external location profiles. The conditional/dependent factor is still the percentage of the take-up rate in a location.

There are 18 internal factors as shown in Table 5. The top internal factor was discovered seven times: affordable costs. According to Queder et al. [35], affordability is one of the characteristics considered, along with age distribution. This is also what several other researchers have conveyed, including Ovando et al [36], who are concerned with price, Shin et al [37], who are concerned with low prices, Liu et al [38], who are concerned with bandwidth prices, Jakopin [39], who are concerned with prices, Gilani et al [40], who are concerned with social factors of price, and Briglauer et al [41], who are concerned with prices and purchasing power. Following that, the research discovered demand forecasting four times. According to Borreau et al. [42], market size, population density, and income level all influence demand forecasting. Meanwhile, Lee et al. [43] predict that demand will include willingness to pay, price range, product bandwidth, and network latency quality. Oughton [44] also discusses the advantages of demand forecasting in order to achieve high take-up and profit from economies of scale that benefit both the company and its customers.

Activation time and marketer availability are mentioned three times. The phrases "broadband quality," "product bandwidth," and "packed product" appear twice in the article. The remaining terms, such as projected income, churn prediction (area), individual churn prediction, subscribe method, product value, ease of acquiring, CSC service quality, presence facilities, low latency, premium services, coverage, and package product, appear just once in the article. Therefore, to concentrate on internal aspects, we suggest those factors that are 50% over the quartile are very important when developing FTTH internet broadband, i.e. affordable pricing, demand projection, number of marketers, internet broadband quality, internet broadband capacity, and product package.

As shown in Table 6, there are 40 external factors. The number of competitors among new and current FTTH services, as well as the availability of FTTH services, rank first in the external location profile. It was mentioned ten times in the articles. According to Reed et al. [49], FTTH services in new or dense residential areas should ideally have two competitors. Meanwhile, Menendez et al. [50] state that the availability of FTTH infrastructure by a single provider is a key factor in addition to age, education, and income.

TABLE V. INTERNAL FACTORS

No	Internal Factor	Occurrence	Article	Quartile
1	Affordable Price	7	[35];[36]; [37]; [38];[39]; [40];[41]	> 75%
2	Demand Forecast	4	[17]; [42]; [43];[44]	> 75%
3	Activation Time	3	[17]; [39]; [40]	> 75%
4	Marketer	3	[34]; [46]; [45]	> 75%
5	Broadband Quality	2	[37]; [43]	> 75%
6	Product Bandwidth	2	[38]; [43]	> 75%
7	Package Product	2	[47]; [53]	> 75%
8	Churn Prediction (Area)	1	[46]	50%
9	Expected Revenue	1	[17]	50%
10	Individual Churn Prediction	1	[46]	50%
11	Subscribe Method	1	[37]	50%
12	Product Value	1	[31]	50%
13	Ease to Obtain	1	[34]	50%
14	CSC Service Quality	1	[34]	50%
15	Presence Facilities	1	[34]	50%
16	Low Latency	1	[43]	50%
17	Premium Services	1	[38]	50%
18	Coverage	1	[39]	50%

Twist [53] mentions the density element and subscriber nine times in the article, followed by the median income per region (GDP area), demographics, skill, and readiness to pay or purchase, which is cited six times. Geolocation that encompasses a city or suburb with Telco infrastructure, as stated by Ali et al [51], has been discovered five times. Income and education level are mentioned four times in the articles; the population of Personal Computers (PCs) and devices, the municipality leader or business leader as stated by Troulos [52], the building/developer/business trade analysis, the minimal competitor bandwidth, and the aerial location are mentioned three times. The article mentions the median population age, English literacy, teenage population under the age of 18, new housing area development, Twitter/citizen perception, and influencer twice. The rest only discovered one. As a result, regarding external factors, we suggest those factors that are 50% or higher in the quartile are important when developing FTTH internet broadband, i.e.: number of competitors/FTTH Availability, density, GDP, demographic, skill, willingness to buy/pay, geolocation, income, education level, PC population, gadget population, municipality leader authority/decision maker, trade analysis, competitor bandwidth, aerial location, median population age, English literate, number of teen age < 18 years, new housing area development, perception/citizen perception, and influencer.

TABLE VI. EXTERNAL FACTORS

No.	External Independent Factor	Occurrence	Article	Quartile	Non Single ISP (>2 Competitor)		Single ISP (No Competitor)	
					Relation	Polarity	Relation	Polarity
1	Number of Competitor (New and Existing) / FTTH Availability	10	[31]; [35]; [36]; [39]; [42]; [45]; [48]; [49]; [50]; [54]	> 75%	Competitor, invest	-		
2	Density (m2)	9	[17]; [27]; [28]; [30]; [35]; [42]; [44]; [49]; [53]	> 75%	Weak	+	Weak	-
3	GDP Area/Income per Area (Median)	6	[27]; [35]; [39]; [42]; [48]; [50]	> 75%	Weak	+	Strong	+
4	Demographic	6	[12]; [27]; [34]; [28]; [43]; [48]	> 75%				
5	Skill	6	[12]; [25]; [39]; [41]; [43]; [50]	> 75%				
6	Willingness to Buy/Pay	6	[31]; [38]; [41]; [43]; [45]; [47]	> 75%				
7	Geolocation	5	[17]; [43]; [44]; [46]; [52]	> 75%				
8	Income	4	[43]; [47]; [48]; [50];	> 75%				
9	Education Level	4	[41]; [43]; [48]; [50];	> 75%	Strong	+	Strong	+
10	PC Population	3	[35]; [39]; [43]	> 75%				
11	Gadget Population	3	[35]; [39]; [43]	> 75%				
12	Municipality Leader Authority / Decision Maker	3	[12]; [31]; [51]	> 75%				
13	Building / Developer/Business Utilities / Store/Corp / Hospital / School (Trade Analysis)	3	[28]; [51]; [54]	> 75%				
14	Competitor Bandwidth (min.)	3	[42]; [43]; [49]	> 75%	High Speed	+		
15	Aerial Location	3	[28]; [30]; [35];	> 75%				
16	Population Age (Median)	2	[35]; [50]	50%	Strong	-	Strong	+
17	English Literate	2	[39]; [48]	50%	Strong	-	Strong	-
18	Teen age < 18 years	2	[43]; [48]	50%	Strong	+	Strong	+
19	New Housing Area Development	2	[42]; [49]	50%				
20	Perception/Citizen Perception	2	[34]; [54]	50%				
21	Influencer	2	[41]; [54]	50%				
22	Competitor Price	1	[36];	25%				
23	Number of Competitor Wireless	1	[35]	25%				
24	Customer Profile	1	[46]	25%				
25	Internet Service Delivered	1	[46]	25%				
26	Population	1	[47]	25%				
27	House/Building/Land Price (Median)	1	[48]	25%	Strong	+		
28	Race	1	[48]	25%				

E-mail:author's email

No.	External Independent Factor	Occurrence	Article	Quartile	Non Single ISP (>2 Competitor)		Single ISP (No Competitor)	
					Relation	Polarity	Relation	Polarity
29	No. Of Follower	1	[54]	25%				
30	Developer/Constructor/ISP Colabs	1	[37]	25%				
31	Fitur to be User	1	[12]	25%				
32	Teleworker	1	[12]	25%				
33	Commercial Attractiveness	1	[31]	25%				
34	CSC Usefulness	1	[34]	25%				
35	Product Belief	1	[34]	25%				
36	Student/College Student	1	[43]	25%				
37	Online Transaction	1	[25]	25%				
38	Business Digitalization/e-initiatives	1	[25]	25%				
39	Rural Road Distances	1	[28]	25%				
40	External Factor (Generic)	1	[34]	25%				

D. Answering Research Question #3 - What are methodologies to predict the take-up rate in FTTH internet broadband area?

In this section, we explore in the articles what methodology can be used to predict the percentage of take-up rate in the area using an independent factor described in RQ#2. Only two indexing services gave results to the query, ScienceDirect returned two articles and ProQuest one article.

In this RQ#3, we did not classify the results and mainly focused on the methodology. The first methodology, Iwashita et al. [54], used the graph model to track the human behaviour movement of a person in and out of an area with Information, Communication, and Technology (ICT) installed infrastructure. This person must socialize and communicate to influence their colleague to use the Internet. The internet service was spread by word of mouth to a colleague with similar preferences. Therefore, the adopter would induce internet service diffusion to many individuals also. Finally, many-to-one spread-in areas and many-to-many spread-out areas are forms of internet service diffusion. The demand forecast for the ICT-installed area also was measured. Next, in the not yet ICT-installed area, the estimated demand was predicted by multiple regression of the area's characteristics using demographic data and potential demand data of a similar characteristic site in the existing ICT-installed area.

Meanwhile, Bermolen and Rossi's [55] second technique predicts the take-up rate using Support Vector Regression (SVR), which is employed in link load projections based on prior measurements and regression. The parameter of the take-up rate was analyzed with sensitivity analysis, trained, validated, created the correlation structure, and evaluated the method. The SVR functions output is:

$$\hat{y} = f(x) \quad (1)$$

Where:

$x = (\lambda_{k-(d-1),\ldots,} \lambda_{k-1,} \lambda_k)$ (2)

$y = \lambda k + 1$ (3)

λk = average traffic load measured in the certain interval

d = dimension of input

x = attribute of network or area

y = actual future value

$\hat{y}$ = predicted future value

To evaluate, tune the SVR functions, and find the best attribute in the x variable, Bermolen and Rossi [55] used the Root Mean Square Error (RMSE). It was also used to measure the quality of the estimator, its unbiasedness, and quantify the prediction accuracy. The formula for RMSE is as follows:

$$R = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y - \hat{y})^2} \quad (4)$$

Where:

R = Root Mean Squared Error (RMSE)

n = number of times the summation happens

y = Actual Value

$\hat{y}$ = Forecast value

On the other hand, Mycek and Zotkiewicz [56] presented a model and method for the optimized trajectory of the multi-period network evolution of the FTTH network link deployed. The model continued with the business and cost model of multi-period network evolution. They come from a mathematical and technical telecommunications model perspective. In representing the demand vector over a period was defined by {dt}t€τ, the sequence of network configuration was described by {Xt}t€τ, and the range

network configuration was characterized by {Rt}t€τ. Sequences network configuration Xt is compatible with demand vector DT in the range of Rt. The vector representation is used for developing cost-effective network sequences of demand vectors and can be evaluated to optimize network configuration. The cost function of it can be presented in cs (x), x € X.

$$cs(x) = nH(x)\zeta H + nD(x)\zeta D,\ x \in X \qquad (5)$$

where:

- ζH and ζD show the cost of a single fiber in sequence connection of the Central Office to the Distribution Point and the Access Point.
- The value of ζH and ζD is assumed to be 40 and 50, for further analysis. The take-up rate is simulated by the use of a demand vector and cost function.

As revealed by Limbach et al. [28], the first three years of take-up rate were, consecutively, 25%, 50%, and 70%. Next, in the remaining investment timeline, the churn rate and customer acquisition (take-up) rate are equal or remain constant (the same). Therefore, during the fourth to tenth years of the investment timeline, the take-up rate is considered equivalent to the churn rate. So, some attributes related to churn can be viewed as the same as the take-up rate. Several methodologies of churn rate are evaluated and used to process the take-up rate prediction.

4. CONCLUSIONS

Indirectly referring to a high TUR in a region, this study adds to the conclusions of a comprehensive analysis of the definition and components of a high-potential customer of FTTH internet broadband. As a result it can be utilized to gauge and forecast the appropriate number of potential users that must be considered in the financial feasibility research. The systematic review and analysis were conducted using three indexing services: Google Scholar, ScienceDirect, and ProQuest. From 1987 to 2022, we discovered 192 documents that fulfil the query. Those articles were extracted to become 41 articles using inclusion-exclusion criteria to respond to the three research topics outlined. All those articles are deemed of high quality for responding to research questions and findings about FTTH internet broadband issues.

In response to RQ #1, based on findings from 32 articles, the take-up rate is a critical factor or acts as the focus in FTTH Internet broadband business along with ARPU. TUR relates to providing the service to the newly acquired user. We define TUR as the percentage ratio between customers connected to internet broadband connections and the total available connections. From the perspective of customer acquisition, TUR, and churn rate prevention are all related to increasing the number of served customers.

The take-up rate is the dependent variable, and it is related to 18 independent variables of internal factors and 40 independent variables of external factors. Seven independent elements are derived from internal characteristics that exceed the data's median, i.e.: affordable pricing, demand projection, number of marketers, internet broadband quality, internet broadband capacity, and product package. Furthermore, 21 independent variables of external factors are more than the data collection's median, i.e.: number of competitor/FTTH Availability, density, GDP, demographic, skill, willingness to buy/pay, geolocation, income, education level, PC population, gadget population, municipality leader authority/decision maker, trade analysis, competitor bandwidth, aerial location, median population age, English literate, number of teen age < 18 years, new housing area development, perception/citizen perception, and influencer. RQ #2 is answered and explained by those dependent and independent components.

From our findings, there are three methodologies for measuring TUR that is related to the influencer-related model and continue with multiple regression, support vector regression, and the optimal trajectory of the multi-period network evolution of the FTTH network link deployed. One conclusion that should be taken into account is that the take-up rate projection in the remaining years of the FTTH investment timeline may be processed using the churn approach.

This systematic review and analysis is open to location-based criteria and is not limited to rural areas as usually found in other studies. The study's results can be used by ISP management to decide suitable places in developing internet broadband areas and for the customer who is still in the coverage area and willing to connect their site to FTTH internet broadband services. For a Geographical Information System (GIS) developer or asset management developer, this result can be used as a benchmark to predict areas that have a high take-up rate.

Researchers, network planners, marketers, Chief Financial Officers (CFOs), and Chief Information Officers (CIOs) can utilize the results of this systematic review and analysis as a benchmark for optimizing TUR. It includes collected, extracted, and connected dependent and independent components that are measured and predicted using various methodologies. Several activities are still related to the research approach. Indicating TUR can also be used for related projects, such as estimating future wireless Internet users at a 4G or 5G base transmitter tower, prospective customers in a retail establishment, or efforts to entice potential customers to company locations that have already been established or will be soon. For more accurate outcomes, estimates in the form of projections can be made based on the independent variables owned by each use case.

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