DEVELOPMENT OF FORMULA & APPLICATION FOR CALCULATING INTERNET BANDWIDTH REQUIREMENTS FOR LOCAL GOVERMENT

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Abstract. *This Systematic Literature Review aims to create a new formula model for calculating bandwidth requirements for local governments conducted in one of the metropolitan cities in East Java to ensure the accurate allocation of regional budget expenditures. To obtain comprehensive literature, a literature review involving Scopus-indexed journals was conducted, with a total of 30 publications thoroughly analyzed to ensure detailed information validity. Additionally, concise explanations and overviews were provided to facilitate readers in understanding the presented information explicitly. There were challenges in finding modeling related to bandwidth calculations, as most models used mathematical calculations without considering real-world conditions and limitations of existing models. However, a relevant model was found that could be adapted with other supporting factors, such as Nielsen's Law and field conditions. To achieve precise formulas, gradual testing and evaluation are necessary to refine the created formula. The formula resulting from this study has the potential to assist local governments in estimating bandwidth usage and help academics in developing bandwidth calculation formulas for both governments and organizations. These findings can inspire and guide researchers in further developing and improving bandwidth calculation formulas.*

Keywords: *Bandwidth Calculation, Bandwidth Requirement, Local Government, Nielsen's Law.*

1. INTRODUCTION

Smart City is a concept of urban development that integrates information and communication technology (ICT) to enhance the quality of life for residents and improve public service efficiency (Pour et al., 2023). In this context, the Sustainable Public Budget Efficiency (SPBE) index is directly related to the efficient management of sustainable public budgets. The SPBE index measures the efficiency of public budget management in achieving sustainable development goals and is considered one of the indicators of a city government's success in implementing Smart City programs.

Therefore, the budget allocated for building a Smart City must be efficient and purposeful, including the budget for internet expenses. Efficient internet budget allocation is considered important for a region because proper budget planning allows the city to allocate available funds for better internet infrastructure, including network development, speed enhancements, improved accessibility for residents, and the ability to provide better public services to its citizens. With an optimized internet budget, the city government can enhance opportunities for its residents to access information, online healthcare services, e-commerce, as well as various social and cultural activities in the community (Edeagu et al., 2023). It can also stimulate economic growth through global digital market industries. Internet usage

also serves as a technological solution for government performance, such as e-government, smart urban management systems, and other online-based services. This enables the government to communicate more effectively with citizens, provide faster services, and reduce bureaucracy.

By prioritizing the efficiency of the internet budget, a city can harness the full potential of the internet to improve residents' quality of life, drive economic growth, and enhance government efficiency.

The usage of the internet in a city needs to be accurately measured and recorded in real-time because such data provides insights into the demand and needs for internet access in a specific area. It helps decision-makers allocate resources effectively to improve connectivity and network capacity. Internet usage data can also provide an overview of how far internet access has reached in society and whether there are digital access disparities among different social or geographical groups. Calculating internet usage is particularly important for governments to make informed decisions and policies regarding infrastructure development, target setting, program evaluation, and the development of services that meet user needs. The purpose of this research is to create a solid formula that can facilitate the planning, allocation, and management of bandwidth for local governments, in order to ensure well-controlled, effective, and efficient internet usage.

2. BACKGROUND

The local government's need for internet as a supporting tool for work and information services for residents is very high, influenced by the current digital world's development. Therefore, a significant budget is required for internet procurement in each respective region. In this regard, it is crucial for the local government to allocate a specific budget for bandwidth expenses. Technological advancements have also made local governments increasingly reliant on information technology and the internet for their operations. The internet is used for communication, accessing information, public services, data management, and much more (Wu et al., 2023; Khangura et al., 2019). Hence, effective and efficient budget planning for internet expenses is vital to ensure the smooth functioning of local government operations.

The demand for internet access is increasing across various sectors of society (Muhammad et al., 2021). Education, business, healthcare, transportation, and many other fields require reliable internet connections. The local government needs to allocate adequate funding to ensure sufficient internet access for residents, businesses, and other institutions in their respective areas. The existence of programs initiated by the central government has led many local governments to undergo digital transformation and become Smart Cities. This involves the use of information technology and the internet to enhance efficiency, public services, citizen participation, and the quality of life in the city or region (Honga et al., 2019). In this context, budget planning for internet expenses becomes essential to support the implementation of planned digital transformation programs and projects.

Effective budget planning for internet expenses helps local governments in proper financial management. By allocating sufficient funds and prioritizing expenditures related to the internet, local governments can avoid wastefulness, ensure the availability of adequate resources, and optimize the results of investments in internet infrastructure and services. Well-structured budget planning for internet expenses can have a positive impact on improving public services

(Saputro & Ristanto, 2021). With adequate internet access, the local government can provide more efficient, transparent, and easily accessible online services to the community. This can enhance citizen satisfaction, promote citizen participation, and improve the effectiveness of governance. Considering these backgrounds, budget planning for internet expenses is crucial for local governments to support the sustainable development of information technology and the internet, while providing maximum benefits to the community and local government. Moreover, proper budget efficiency can also influence the SPBE index of the respective region as one of the indicators of success in implementing Smart City programs, particularly in terms of budgeting.

However, in practice, budget allocations are often based on previous periods and increased based on the requests of local government agencies without detailed calculations, which can lead to budget inflation. To determine specific bandwidth needs, the government can monitor and analyze network usage over a certain period comprehensively within each agency (OPD) and public facilities that have internet access. By conducting such measurements, it is possible to determine the average data transfer speed required, the amount of bandwidth used, and whether there are peak usage periods that require larger bandwidth. This approach allows for a more accurate determination of bandwidth needs to meet optimal network usage requirements.

3. RELATED WORK

The functions of bandwidth allocation and management play a crucial role in maintaining network service quality, ensuring fairness in bandwidth access, managing and optimizing the use of network resources, and addressing performance issues such as traffic congestion, overload, and conflicts in bandwidth usage. This research discusses and compares the existing formula and methods of bandwidth allocation and bandwidth management.

The authors of (Said, 2023) explains that bottlenecks often occur due to the heterogeneous IoT environment. To address this issue, the researchers propose a bandwidth control scheme consisting of bottleneck detection methodology, bandwidth prediction approach, bandwidth usage reduction mechanism, and bandwidth management model. This model aims to reallocate bandwidth, particularly in cases of normal and prioritized data, and it was tested using NS-3. Simulation results prove that the proposed bandwidth control scheme significantly improves the efficiency of the IoT environment and mitigates the negative impact of bottlenecks. In Figure 1, it is explained that to ensure the effectiveness of the proposed scheme positively, the simulation results are compared with well-known machine learning and deep learning techniques: long short-term memory (LSTM), gated recurrent unit (GRU), autoregressive integrated moving average (ARIMA), multi-layer perceptron (MLP), and deep reinforcement learning (DRL).

Figure 1. An Overview of Bottleneck detection Methodology

However, this scheme is not suitable for implementation in local governments as it tends to be complex, requiring a lengthy and time-consuming process. Therefore, in our research case, this method cannot be applied.

In (Sukarsa, Piarsa, & Bagus, 2021) the authors explained that organizations in the current era are always accompanied by the use of information technology, especially computer networks, which facilitate communication. However, organizations lack tools to handle security and bandwidth management issues in large quantities, resulting in wasteful use of bandwidth for unproductive purposes. This is due to the high cost of available tools in the market. Therefore, the authors developed a bandwidth management system that shows in Figure 2 called Remote Authentication Dial-In User Service (RADIUS) and MikroTik RouterBoard, with lower costs.
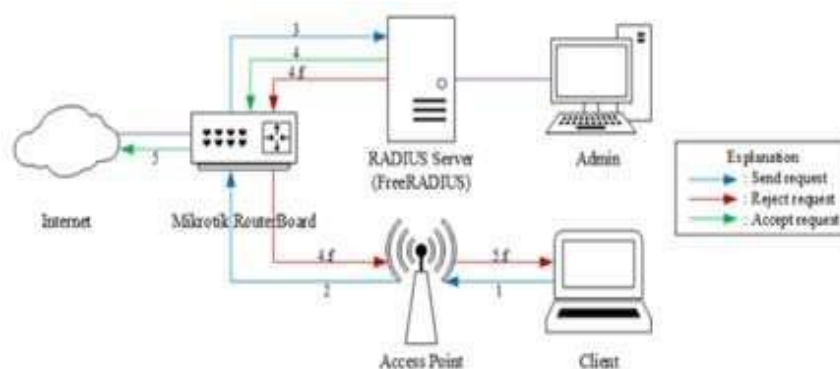

Figure 2. System Overview

This method can also be integrated with a MySQL database to determine appropriate data quotas for clients. Despite its advantages, this method is still considered unsuitable for local governments due to budget limitations required for bandwidth management. Therefore, further research is needed to explore bandwidth management approaches with limited budgetary expenditures.

The authors of (Azami & Narm, 2921) focused on provides a solution for automatically transferring to a higher bandwidth network when the network capacity is full. This solution can be implemented using bandwidth management, while considering the threshold of packet loss in each network. If this threshold is exceeded, the existing network switches to a higher-capacity network, effectively addressing bandwidth and network quality issues, thereby improving customer satisfaction. The first step is to design a fuzzy PID controller for the existing network to control congestion and utilize it effectively. This controller provides better results in terms of output response and various other factors compared to classical controllers. However, this method has a high level of complexity as all processes are technically performed, which cannot be easily executed by many individuals.

The study by the authors of (Guojun, Yundeng, & Tonghui,2023) explains that LAN has become a crucial requirement for Passive Optical Network (PON). However, existing OLAN schemes generally isolate the LAN function from regular PON, resulting in rigid allocation of transmission resources. To address this issue, the author proposes a new bandwidth allocation scheme for the PON system that determines when to switch its operating mode that shown in Figure 3.
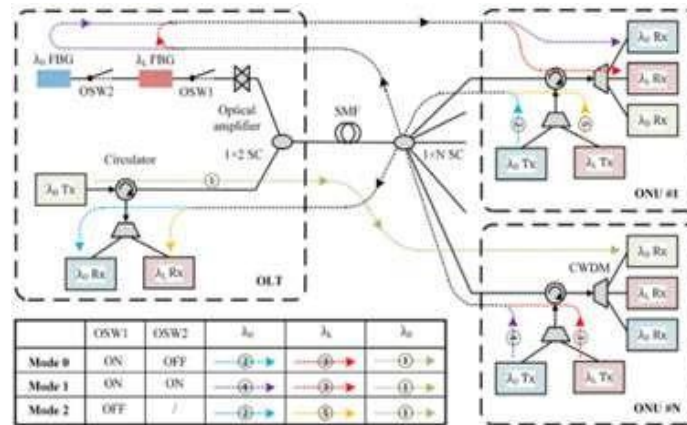
Figure 3. The Schematic Diagram of The Proposed PON System

This scheme aims to reuse unused timeslots due to half-duplex LAN transmission by sharing timeslot and wavelength resources between upstream and LAN transmissions. The method demonstrates better results compared to traditional schemes in terms of average latency, network throughput, and load balancing performance. However, this method requires individuals with strong networking capabilities as it involves technical aspects and requires a significant amount of time for planning and estimation.

Additionally, the implementation of this method in local governments may not be suitable due to the substantial budget required and its lack of precision.

Researchers in (Muhammad et al., 2021) discusses the fact that future data demand is a relevant issue in the implementation of Next Generation Access (NGA) networks. The authors compare the predicted broadband demand results for Germany, the UK, and the Flemish region and the impact that the difference between user profiles and household structure has on the forecast of bandwidth demand.. The authors explain that the market potential can be projected and mapped based on applications and bandwidth needs, user profiles, and household-level population structure. This potential is also influenced by socio-demographic factors. The researchers used the WIK market potential model that shown in Figure 4 to estimate bandwidth, which is the most suitable method for creating a formula for bandwidth requirements for local governments with adjustments based on field conditions.
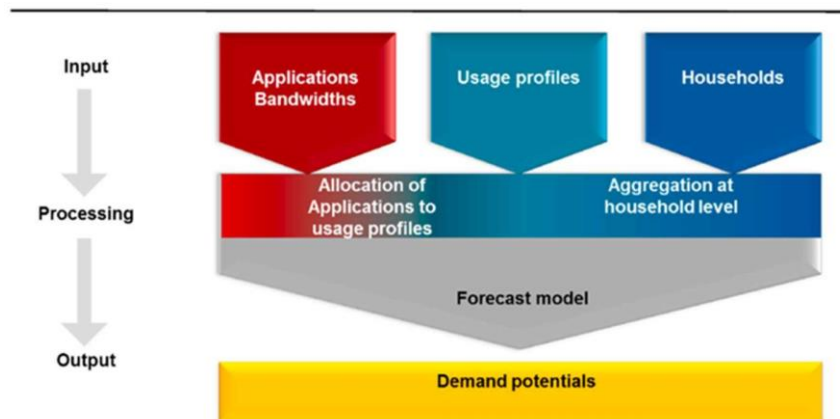

Figure 4. Methodology of the WIK market potential model

Previous research has focused on highly technical aspects and hardware-related discussions, while this study focuses on bandwidth management that involves people and existing bandwidth usage history data. There is a need for a systematic literature review regarding methods for calculating bandwidth allocation and management. Our research addresses the issue of the need for a method and formula for calculating bandwidth requirements by conducting direct observations. In this study, three questions are formulated to clearly demonstrate the importance of formulating a bandwidth calculation formula, while considering the increasing needs in the future perspectives.

4. LITERATURE REVIEW

4.1 Research Question

1. How the formula work to determine the bandwidth needed by the local government?
2. Does the position, variety of jobs, and applications used affect the amount of bandwidth usage?
3. Is the bandwidth usage in the local government effective and efficient?

4.2 Search Criteria

There are various studies regarding bandwidth allocation for companies, but there is no research specifically discussing how to determine the required bandwidth for a local government or the applicable formula. Due to this limitation, the articles considered in this Systematic Literature Review (SLR) are sourced from the period between 2015 and 2023. Referring to the research questions and themes proposed, we present several related search terms, including "Bandwidth Allocation," "Bandwidth Usage," "Internet Usage," and "Internet Budgeting." After conducting searches across various international journal sources, we selected a series of related searches that provided us with relevant research articles as references for writing this SLR.

4.3 Data Source

For this SLR project, various data sources were analyzed. The majority of journals were obtained from Elsevier, Scopus, and Google Scholar, where the articles reviewed consisted of conference reports, research journals, and books relevant to the research topic. Additionally, the researchers also read various articles from reputable publishers such as Science Direct and Google Scholar, which were included in the review. The figure below shows the result of source finding. The mapping results from the 30 collected publications regarding bandwidth allocation methods in the 2018-2023 period were obtained using the keywords "Bandwidth Allocation" and "Bandwidth Management" through publications indexed in Scopus, which were then processed into a mapping using VOSviewer. Based on the mapping results, two major clusters were identified. The most discussed topic was management, which was related to bandwidth allocation, architecture, sharing, internet, and IoT. This was followed by resource allocation. Resource allocation was further divided into two smaller clusters: device and frequency band, which were related to Allocation plan, communication system, and wireless resource allocation.
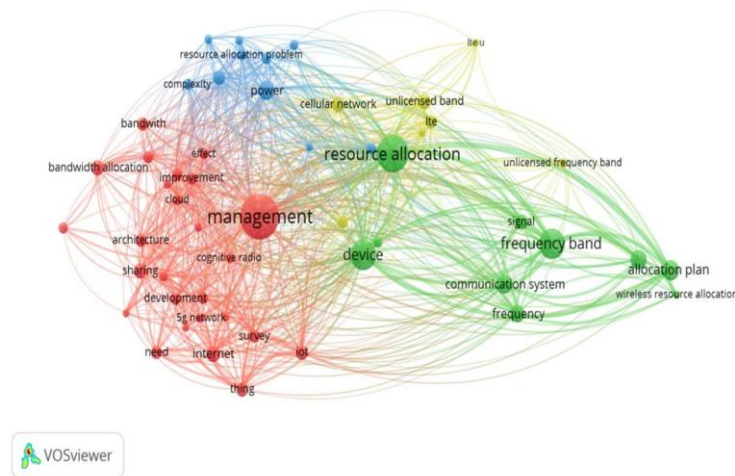
Figure 5. Network Visualization Assessment Map for Bandwidth Management

In Figure 7, the Visualization Overlay is shown, depicting the current state of research on Bandwidth Management. Each circle has different colors, representing the average year of publication across all study fields and related keywords. Referring to the results of the Visualization Overlay mapping, it can be said that articles discussing bandwidth management tend to be represented by dark blue, indicating that the field emerged in 2019, while the allocation plan field is represented by light blue, indicating that the last discussion on the topic was in 2020. Both of these fields were not further discussed in the period from 2020 to 2023, indicating that there is an opportunity for further exploration and that the planning of the bandwidth management formula has the potential for high novelty and innovation.
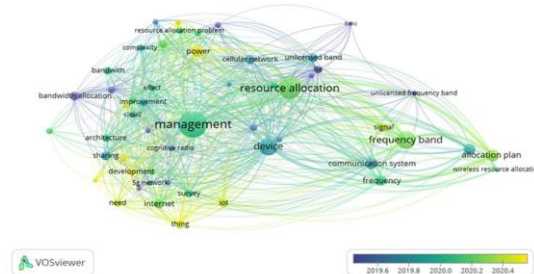

Figure 6. Overlay Visualization Assessment Map for Bandwidth Management

4.4 Article Selection Process

The perspective of a research article is considered the most important factor in determining whether the article is eligible for inclusion or not. The tactic used to select articles begins with formulating research questions, as mentioned above. By defining criteria, articles that can support the search and selection process are identified, such as articles published no more than five years ago.

After obtaining initial research articles based on the framework and keywords, we reviewed the bandwidth allocation and bandwidth management schemes discussed in each article. The search procedure concluded by categorizing the bandwidth allocation and bandwidth management schemes to ensure the comprehensiveness of this study. Some articles were eliminated as they were deemed less relevant based on the title used and the strength of the information

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conveyed.

Out of the numerous articles collected by the researchers from various journal sources using the search framework, the reference articles were published between 2018 and 2023 in various high-quality journals and other publications.
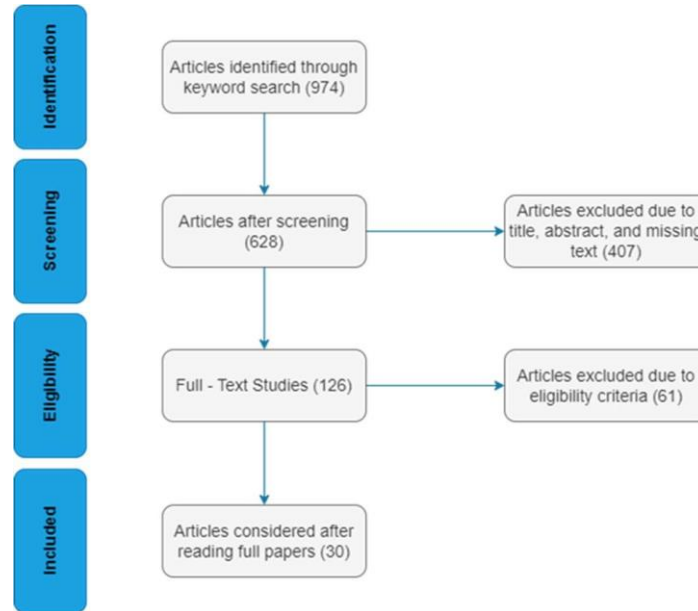

Figure 7. Article Selection Procedure

As shown in Figure 3, a total of 974 research articles have been collected using the mentioned search keywords. These articles were published from 2018 to 2023 in various high-quality journals and other publications. To select compelling research articles, inclusion and exclusion criteria were applied, as indicated in Table 1, resulting in a reduction to 628 articles. Based on their abstracts and titles, the selection was further reduced to 126 articles related to the chosen domain. From this point onwards, these 126 articles were examined, and 30 articles were ultimately selected specifically discussing bandwidth management and bandwidth allocation, both technically and based on theory or models.

Tabel 1. Inclusion and Exclusion Criteria

Criteria	
Inclusion	The Publication were published in well-reputed journal
	The Publication was written in English and Peer-reviewed
	The titles, abstracts, or even keyword focused on Bandwidth Management and Allocation
Exclusion	The Publication were not written in English and not Peer-reviewed
	The Publication were conference article
	The Publication not focused on Bandwidth Management and Allocation

DISCUSSION

The literature review uncovered several findings across each research question, as discussed below:

Q1. How the formula work to determine the bandwidth needed by the local

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government?

In designing the formula to calculate the bandwidth requirements for local governments, the researchers conducted direct observations in the field and identified several factors that can influence bandwidth requirements, namely:

1. Number of users: The formula can consider the number of users who will be connected to the network. The more users connected, the greater the bandwidth requirements.

2. Types of applications and services used: The applications and services used by local governments may require different bandwidth. For example, if there is heavy usage of applications such as video conferencing or large data transfers, the bandwidth requirements will be higher.

3. Volume of data sent and received: The formula can take into account the amount of data generated, sent, and received by the local government. The larger the volume of data to be handled, the greater the bandwidth requirements.

4. Desired performance level: If the local government wants a fast and responsive internet connection, the bandwidth requirements will be higher to ensure adequate performance.

5. Estimated growth: The formula can consider the expected future growth in terms of users, applications, and services based on Nielsen's Law. By estimating this growth, the bandwidth requirements can be formulated to meet future needs.

Therefore, the researchers decided to adapt the WIK market potential model combined with Nielsen's Law. Supporting data such as the number of users, historical data on bandwidth usage, applications used, and the supporting factors will also be considered in creating the modeling for the Bandwidth Calculation Formula for local governments. After the new formula is developed, it will be tested with various government departments and then evaluated to obtain an optimal and precise calculation formula.

Q2. Does the position, variety of jobs, and applications used affect the amount of bandwidth usage?

Factors that are considered to influence bandwidth usage when working in local government include position, job title, applications used for work, and workload. Here are some explanations of why these factors can affect bandwidth usage:

1. Position: An individual's position within the organization is expected to influence bandwidth usage. For example, positions such as programmers or software engineers may require the use of applications that demand high bandwidth to perform their tasks. This may not apply to administrative staff whose tasks may involve less heavy application usage, resulting in lower bandwidth requirements.

2. Job Title: Job titles can also impact bandwidth usage. Certain positions, such as department heads or directors, may be more likely to use applications that require high bandwidth for important video conferences or sending relatively large files. On the other hand, other positions that do not require the same application usage may have lower bandwidth requirements.

3. Workload: The level and type of workload can also affect bandwidth usage. Assuming someone is involved in tasks that require video streaming or access to large online resources, such as data analysts, they would require higher bandwidth compared to someone with lighter workloads or tasks that mainly involve communication via email and working on regular text documents, resulting in lower bandwidth needs.

Additionally, there are other factors that can influence bandwidth usage, such as the sector of the local government job. For example, the Communication and Information Agency may have higher bandwidth requirements due to their work in developing applications and coordinating the government's intra-network, which requires significant bandwidth access. On the other hand, the Social Services department may have lower bandwidth requirements as their tasks tend to focus on text communication and access to regular documents. These factors greatly impact the planning of bandwidth needs in the work environment to ensure that each individual has adequate access according to the demands of their work.

Q3. Is the bandwidth usage in the local government effective and efficient?
To determine the level of effectiveness and efficiency in the usage of bandwidth in local government, direct field observations are necessary. This involves examining historical data on bandwidth usage and checking for the presence of network infrastructure planning and adequate network infrastructure. To ensure effectiveness and efficiency, good management and monitoring are required in the network usage sector, along with rules for identifying and addressing issues, as well as resource utilization optimization.

5. OPEN RESEARCH ISSUE AND TREND IN BANDWIDTH MANAGEMENT
There are still some areas that need to be explored by researchers. Here some of the open issues are discussed below:

5.1 Internet Usage Measurement
In an era where many internet data packages have limited quotas, measuring internet usage becomes important to manage and control data usage. By monitoring data usage, users can avoid exceeding the quota set by the service provider and prevent additional charges. This can also help identify applications or services that consume the majority of data, allowing users to optimize their internet usage. Further research that could be conducted by other researchers is to find tools, both in the form of hardware and software, that are capable of monitoring an organization or personal data usage in terms of both the amount of bandwidth used and how that bandwidth is allocated.

5.2 Security and Privacy in Networks
An insecure network is vulnerable to attacks from unauthorized parties. Security threats such as malware, viruses, ransomware, and other cyber attacks can result in financial losses, theft of personal or organizational data, and operational disruptions. The misuse of data can cause harm to individuals or organizations. In Indonesia, there is an IT law that regulates that organizations must ensure they meet the security and privacy requirements set by the regulations to avoid penalties and fines. Therefore, the development of effective security techniques and protocols to protect bandwidth and data within the network is necessary to reduce the risk of disruptions.

5.3 Bandwidth Measurement and Analysis
By monitoring bandwidth usage, organizations can understand how much resources are being utilized by each department or user. This enables more efficient management and proper resource allocation. By identifying excessive or inefficient usage, organizations can take necessary actions. Additionally,

organizations are able to identify bottlenecks or weak points in their network infrastructure, allowing them to make necessary improvements for optimal network performance and avoidance of disruptions. Further research can be conducted to develop methods and tools for measuring and analyzing the quality and performance of bandwidth in a network.

5.4 Budget Planning

One of the most important aspects for organizations is managing and controlling their expenses related to network infrastructure. With a better understanding of how bandwidth is used, organizations can identify unnecessary or excessive usage that can result in additional costs. This enables them to optimize resource utilization and avoid unnecessary expenses.

CONCLUSION

Based on the systematic literature review of 30 selected and thoroughly reviewed publications regarding the design of bandwidth requirement calculation, it was found that there is still a limited number of formulas that can be globally applied, and there is no formula designed universally for easy implementation. Based on the above information, further research in this field needs to be developed to serve as a reference and guide for researchers and academic practitioners. In the development of bandwidth calculation formula models, supportive factors also need to be considered, combining various models and laws related to bandwidth calculation to ensure that the proposed formula is highly accurate and precise. Internal factors such as the needs of local governments also need to be taken into account when designing bandwidth planning to produce relevant and effective designs that can be applied appropriately. This research also indicates the obstacles that need to be anticipated and overcome in modeling bandwidth calculation formulas, particularly in determining the appropriate formula calculation for local governments that can be easily applied and implemented across all departments.

In summary, this literature review explains the need for further research to analyze and address the research gaps in existing bandwidth calculation modeling. The developed formulas should be flexible and modular for ease of development and implementation by users and meet the bandwidth allocation needs of local governments. It is hoped that this research can contribute to knowledge and provide valuable guidance for researchers, practitioners, and particularly decision-makers in local governments in implementing accurate bandwidth allocation formula models to minimize regional budget expenditures.

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