Storage Media Selection for Raspberry Pi-Based Office Application Server: A Review

Paul Michael Z. Labis
Caraga State University

Jaymer M. Jayoma
Caraga State University

https://doi.org/10.5109/7395654

出版情報：Proceedings of International Exchange and Innovation Conference on Engineering & Sciences (IEICES). 11, pp.1139-1144, 2025-10-30. International Exchange and Innovation Conference on Engineering & Sciences
バージョン：

Storage Media Selection for Raspberry Pi-Based Office Application Server: A Review

Paul Michael Z. Labis [1], Jaymer M. Jayoma[2]
[1]Caraga State University, [2]Caraga State University
Corresponding author email: jmjayoma@carsu.edu.ph

Abstract: *When used as a lightweight office application server, the Raspberry Pi is becoming more and more popular in small enterprises and educational settings due to its low cost and small size. SD cards, USB flash drives, external HDDs, and SSDs are among the important storage solutions that are examined in this study. The research concentrated on factors pertaining to cost, energy efficiency, performance, and dependability. According to benchmark results from recent research, SD cards continue to be the most affordable option for simple applications, but SSDs perform better in terms of performance and durability. HDDs are less desirable because of their mechanical susceptibility, while USB flash drives provide a more balanced option. Based on certain use cases and resource constraints, this article offers useful insights for choosing the optimal storage systems by contrasting study findings with real-world implementations.*

Keywords: Raspberry Pi, Storage Media Benchmark, Low-Cost Office Application Server

1. INTRODUCTION

The Raspberry Pi's price and versatility made it a popular option for home or basic office servers. One of its best qualities is affordability. The Raspberry Pi functions as an inexpensive server solution that drastically reduces the amount of money normally needed to set up a cloud storage system. For small and medium-sized enterprises, which probably have limited resources, this makes it especially beneficial [1]. The Raspberry Pi is once again a cost-effective option for managing data and duties, as evidenced by another study that showed it can function almost as effectively as conventional servers [2].

Along with the budgetary advantages, the Raspberry Pi's small size allows for flexible installations, which makes it perfect for offices with limited space. Its small size, for instance, makes it possible to install several devices together, increasing performance without requiring the significant upfront investment that larger servers would normally need [3]. Because of its portability, more space may be used at home or in the office.

Furthermore, the Raspberry Pi isn't limited to easy activities. Because of its complete Linux OS, it can manage cloud services, real-time apps, and even data analytics [4]. It's also helpful for monitoring setups, tracking conditions and performance with sensors and IoT technologies [5]. Because of its affordability, portability, and small size, the Raspberry Pi is a popular platform among companies in the modern economy.

When utilizing a Raspberry Pi for a basic server setup, selecting the appropriate storage type is crucial, particularly in situations when funds, space, and energy are restricted. According to a study conducted at Ibn Khaldun University's CSN Laboratory, students' access to and sharing of data has increased since a basic NAS (Network Attached Storage) was put up using a Raspberry Pi 3B+ and an Open Media Vault. They were able to employ a centralized system that operated more quickly and effectively in place of USB devices, which are frequently slow and inconvenient. This made file management and cooperation simpler for all parties involved [3].

Choosing the right storage option is also crucial for improving the Raspberry Pi's functionality, performance, and dependability. Storage has a direct effect on the Raspberry Pi's functionality, particularly whether it serves as a server or a data storage device. Ritzkal et al., (2023) study, for instance, shows that slower, lower-quality microSD cards' intrinsic limitations might result in system bottlenecks that ultimately impact user experience and operational efficiency [3].

This researcher's primary goal is to investigate and assess the many storage media alternatives for Raspberry Pi, especially considering lightweight server applications like file sharing and storage in homes and offices and educational labs. The purpose of this review is to provide information on how storage decisions impact system performance based on scholarly research and real-world case studies.

This review's focus is on storage solutions that work with Raspberry Pi models and are both affordable and useful. To help system designers, educators, and hobbyists make well-informed decisions that balance deployment convenience, performance, and cost, this article further narrows its scope to cover lightweight server use cases, such as file hosting, classroom data sharing, or personal backups.

2. METHODOLOGY

The literature from academic journals, conference proceedings, and reliable open-access sources that were published between 2015 and 2025 was gathered and carefully reviewed for this review. Peer-reviewed research and case studies that focused on performance, affordability, and deployment simplicity were prioritized. Every article was thoroughly assessed for its applicability to the Raspberry Pi's use as a storage server. Implementations in home, small-office, and educational settings where price and ease of use are frequently crucial factors received particular attention. The chosen sources offer a comprehensive basis for comprehending real-world uses and the viability of storage solutions based on Raspberry Pi.

3. RELATED RESEARCH

We may better grasp the storage media requirements and performance consequences for office servers based on Raspberry Pi by examining recent research and practical applications. Prior studies have demonstrated the versatility of the Raspberry Pi in server applications ranging from educational platforms to Internet of Things systems. These studies also provide light on how system dependability, responsiveness, and cost-effectiveness are impacted by storage selection. This section reviews the use of the Raspberry Pi as a lightweight server, the types of storage media utilized, performance standards, reliability aspects, and considerations for cost, power, and space efficiency.

3.1. Raspberry Pi as a Lightweight Server

One noteworthy application of the Raspberry Pi is in offline learning management systems (LMS). Maro et al., (2023) point to research where Raspberry Pis were used in Tanzanian schools to improve teacher training by offering offline access to instructional materials [6]. Fig. 1, illustrates how the Raspberry Pi may host LMS content and function as a micro-server without having constant internet access.

Fig. 1. Raspberry Pi 5. Source: [7]

Applications for Raspberry Pi can also be found in the Internet of things, where it serves as the foundation for intelligent systems. Research on IoT implementations, for instance, has resulted in systems that leverage Raspberry Pi devices as central servers for data collection and management utilizing modern web frameworks [8].
One well-liked platform for setting up a Raspberry Pi as network attached storage (NAS) is Open Media Vault (OMV). This program enables the Raspberry Pi to function as a file storage server that facilitates file sharing and management via a local area network (LAN). Ritzkal et al., (2023) emphasized the Raspberry Pi's potential to simplify file storage management and the device's widespread use in NAS systems using OMV, while also highlighting the security dangers associated with open ports [9].

3.2 Types of Storage Media Used

External HDDs, USB flash drives, SD cards, and SSDs are the primary storage media types that the Raspberry Pi uses. Each of these media formats has unique advantages and is selected based on the specific needs of the Raspberry Pi application.

- The primary storage medium for Raspberry Pi devices is SD cards. They serve as both the operating system's boot medium and the main storage for data and applications. The Raspberry Pi architecture relies heavily on secure digital (SD) cards due to their small size, portability, and price [10]. SD cards provide the transport of data to and from the Raspberry Pi, enabling applications ranging from simple monitoring systems to complex data logging jobs [10].
- USB flash drives are yet another well-liked storage option. Because USB flash drives have greater read/write speeds than regular SD cards, the Raspberry Pi can be configured to run solely from one [11].
- Compared to traditional SD cards and USB flash drives, external HDDs and SSDs provide a substantial amount of storage capacity and enhanced performance. When users need to store a lot of data or carry out operations that require a lot of data processing, such as video recording systems that employ multiple Raspberry Pis, external storage are crucial [12].

3.3 Performance Considerations and Benchmarks

To correctly evaluate storage media for office application servers based on Raspberry Pis, one must comprehend both the theoretical and practical performance of each option under realistic workloads. This section highlights the performance trade-offs between external drives, SD cards, and SSDs when utilized with Raspberry Pi computers by presenting significant benchmarks from various research.
A study in the CSN Laboratory employed a Raspberry Pi 3B+ configured with OpenMediaVault (OMV) as a NAS server. By comparing file transfer speeds across several platforms, including Windows, Linux, and Android, stable access rights enforcement was verified. The benchmark results showed an average download speed of 2.01 Mbps, an average file upload speed from client to server of 1.66 Mbps, and an average NAS uptime performance of 2.37 Mbps over a 7-day period. Table 1, demonstrate practical throughput constraints when using a Raspberry Pi 3B+ with an HDD in a shared network storage situation [3].

Measuring the server to client file transfer rate

Client	Size file			
	0.00018 MB	4.28 MB	65.90 MB	502.70 MB
Windows	0 Mbps	0.922 Mbps	2.471mbps	3.542 Mbps
Average		**2.01 Mbps**		

Network Attached Storage (NAS) performance

Day of the experiment	Date/time of transfer	Put the data (A)	Transfer time (T)	Speed (Mbps)
1	08-30-2022 / 07:51	786.52 MB	254 s	3.097 Mbps
2	08-31-2022 / 02:30	786.52 MB	353 s	2.228 Mbps
3	09-01-2022 / 09:56	786.52 MB	252 s	3.212 Mbps
4	09-02-2022 / 10:24	786.52 MB	315 s	2.496 Mbps
5	09-03-2022 / 08:50	786.52 MB	312 s	2.520 Mbps
6	09-05-2022 / 10:08	786.52 MB	749 s	1.050 Mbps
7	09-06-2022 / 10:08	786.52 MB	398 s	1.976 Mbps
Average			376.14 s	2.368 Mbps

Table 1. NAS file transfer speed trends from the CSN Lab testing. Source: [3]

However, performance benchmarking on a Raspberry Pi 4B with a 64-bit SSD setup showed notable improvements. In a learning management system (LMS) deployment, the average response time for a medium-sized course viewed by 100 users dropped from 46.9 seconds (32-bit SD configuration) to 35 seconds (64-bit SSD). This illustrates how the SSD outperforms traditional SD cards in terms of I/O performance.

According to the study, performance scaled well up to 40 users, but after that, the Raspberry Pi's CPU limits became a problem [6].

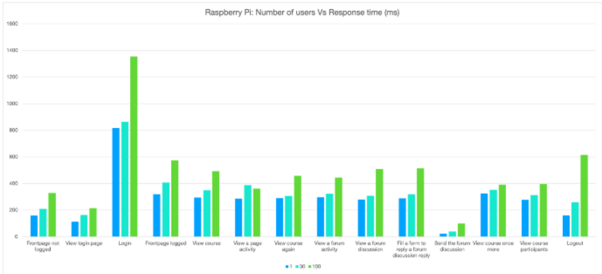

Fig. 2. LMS response times across SD vs SSD storage configurations. Source: [6].

The overall performance of Raspberry Pi systems can be significantly impacted by the choice between SD cards and USB flash drives, Fig 2. SD cards are typically used more commonly for operating systems and apps because the Raspberry Pi has an integrated SD card port. Numerous studies indicate that the throughput and response times of these devices may vary based on their characteristics. Higher-speed SD cards (Class 10 or UHS-I) generally perform better in data read/write tests than many conventional USB flash drives. However, there are currently few specific performance comparisons between SD cards and USB drives for Raspberry Pi use. According to certain research, USB flash drives can perform exceptionally well and, in some cases, may even exceed SD cards [13].

Additionally, a study of different Raspberry Pi operating systems shows that performance is affected by file system and storage type. For example, when it comes to file management efficiency and access speeds, Linux file systems, like ext4, usually outperform FAT32, which is commonly found in SD cards. This suggests that both the underlying software framework and the type of hardware storage have an impact on performance [13].

Fig. 3. Raspberry Pi 5 Model and Connectivity. Source: [7]

The way the Raspberry Pi communicates with external USB peripherals Fig 3, like flash drives, is another crucial element. USB 3.0 drives may perform better than USB 2.0 devices. A Raspberry Pi model with USB 3.0 capability can be very helpful for large data analysis activities or applications that need high data speed, such as video recording [14].

3.4 Storage Reliability and Suitability in Office Use

The two (2) most well-known advantages of SD cards are their portability and large capacity. huge volumes of data may be recorded and stored thanks to its support for huge storage capacity, typically up to 32GB or more. This is particularly helpful in office environments where thorough and frequent data collecting is conducted [15].

Because of their tiny size and high data transmission capacity, USB flash drives are useful for office applications that frequently need to handle huge files. They provide data transfer between computers and integrated systems, like as Raspberry Pi, which are frequently used for prototyping and computing jobs. This easy accessibility, which doesn't require an internet connection, supports productive teamwork and sporadic solo work [16]. The Raspberry Pi's simple architecture makes it a creative tool for computation and automation, enabling even novice users to effectively finish challenging tasks [13].

HDDs' intrinsic mechanical architecture makes them vulnerable to shock and vibration failure. Because they use spinning disks and actuator motors to read and write data, they are susceptible [17]. As Mualfah et al., (2024) have shown that physical shocks can cause HDDs to malfunction, which is an important consideration in an office situation where Raspberry Pis may be moved between places regularly[17].

The main reason SSDs are more dependable than HDDs is because they don't have any moving parts. Under normal operating conditions, SSDs frequently have lower failure rates and longer lifespans due to their design feature [18]. However, a thorough investigation revealed that while SSDs are generally more reliable, higher flash memory densities might lead to higher failure rates in some situations, especially in data center settings [18]. Even while SSDs perform better than HDDs in many aspects, their cost per gigabyte still has a significant impact on whether or not they are used for large-scale storage applications. But as technology develops, SSD costs are going down, making them a more affordable choice for workplaces [18].

3.5 Cost, Power, and Space Efficiency

Generally speaking, SD cards are less expensive than SSDs and HDDs, offering higher capacities at lower prices [19]. Some analyses suggest that SD cards are often the best choice for Raspberry Pi projects due to their affordability, particularly when a large amount of data storage is required for deployment across multiple systems [19].

SSDs consume less power than traditional HDDs, particularly in applications that require for frequent access and fast read/write cycles [20]. On the other hand, especially in low-intensity workloads, USB flash drives provide a balanced power profile and generally consume less energy than HDDs and SSDs [21].

Because SD cards are tiny, they can be easily included into the Raspberry Pi without making the system smaller overall [10]. USB flash drives are widely utilized as easily interchangeable storage choices since they are similarly tiny. Despite their ability to store bigger volumes of data, HDDs require a dedicated power supply and additional physical space, hence they cannot be employed in projects that prioritize compact design [22]. In order to balance form size and performance, SSDs are often designed to work in a range of computer scenarios without significantly changing the overall design [23].

3.6 Future Trends in Rapberry Pi Storage Solutions

The Raspberry PI is poised to become an essential part of contemporary computer systems. The popularity of mobility, distributed architectures, financial restraints, and various rules pertaining to data security and sovereignty all have an impact on this change.

One trend is the use of Raspberry PI's cloud computing capabilities to improve data storage options. By utilizing scalable infrastructures for data storage and combining Raspberry PI devices with cloud services, users can cut costs. Building an architecture that uses Raspberry Pi as a cloud storage server is a cost-effective and resource-conscious solution for small to medium-sized businesses [1].

The use of ZFS and Btrfs advanced file systems on Raspberry Pi is another trend. They provide self-healing capabilities, compression, and snapshots, which are ideal for office settings where data integrity is crucial. However, studies show that the existing hardware specification causes performance to significantly deteriorate under high load [3]. It is only a question of time till it's hardware is upgraded. The Raspberry Pi platform is developing to accommodate more sophisticated and highly effective storage solutions with the recent release of the Raspberry Pi 5, which has PCIe connectivity.

Furthermore, high-performing storage solutions will be necessary for the advancement of edge projects. SSDs will help AI and containerized edge-based applications that use Docker or Kubernetes on Raspberry Pi clusters by utilizing their high-endurance and high-speed read/write capabilities for managing logging, cache models, and effectively storing analytical data [24].

Due to the ongoing decline in flash memory prices and the growth of hybrid storage methods like SD and SSD caching, the Raspberry Pi will continue to be a viable option for scalable and reasonably priced home or office servers. Developers and operations that want to future-proof their Raspberry Pi-based installations must keep up with these advancements.

4. RESULTS AND DISCUSSIONS

This analysis highlights key findings from multiple research and benchmarks evaluating storage media used with Raspberry Pi in lightweight server setups. SSDs frequently outperform SD cards and USB flash drives in terms of performance, especially in multi-user environments like LMS platforms. Utilizing a 64-bit SSD arrangement on a Raspberry Pi 4B produced a notable improvement in reaction time in a 100-user LMS simulation, with a latency reduction of over 25% in comparison to an SD card configuration [6].

USB flash drives offer a reasonable balance between portability and performance, sometimes even outperforming SD cards in terms of read/write rates, depending on the device's model and class [13]. SD cards are still widely used due to their inexpensive cost and native compatibility, although they don't function well under heavy workloads. HDDs are less reliable in mobile or vibration-prone office environments, even with their huge storage capacity [17].

Dependability and power consumption are also crucial considerations. Because SSDs don't have any mechanical parts that can break, they are more robust and energy-efficient even though their initial costs are higher [18], [20]. USB flash drives and SD cards use less energy and are suitable for jobs needing minimal stamina. When it comes to cost and size, SD cards are the most economical and space-efficient choice, which makes them ideal for deployments across a large number of devices [10].

All things considered, the discussion shows that while SD cards may handle basic needs, SSDs provide superior performance and reliability, making them suitable for demanding office applications. USB flash drives are a flexible middle ground.

5. CONCLUSION

For a Raspberry Pi to operate reliably and effectively, especially in office application server scenarios, selecting the right storage media is essential. SD cards are still the most affordable and small alternative, but they are only appropriate for simple, low-demand jobs due to their poor performance under high workloads and limited endurance. Because of their exceptional performance, dependability, and energy efficiency, SSDs are the best option for applications that require sustained data flow and high responsiveness, such multi-user platforms. When weighing cost, mobility, and modest performance requirements, USB flash drives present an appealing choice because they provide a useful compromise: they are more portable and frequently quicker than SD cards, but they are also less expensive than SSDs. This can be used in the implementation for smart city [25] and it could be used in the implementation as a control system for refrigeration [26].

6. RECOMMENDATION

1.For Portability and Interoperability: USB flash drives provide a useful balance between portability, modest performance, and ease of use, making them ideal for situations needing frequent data transfer between devices. They are perfect for temporary storage requirements or semi-mobile setups.

2.Future Research: It is advised to conduct more benchmarking on a wider variety of Raspberry Pi models, including the Raspberry Pi 5, using standardized test suites. Deeper understanding of performance scalability, long-term durability, and ideal settings for various use cases will be possible by comparative testing of different file systems (e.g., ext4 vs. Btrfs) under prolonged workloads.

3.For Enhanced Performance: High-demand applications like learning management systems, web servers, or database hosting should use solid-state drives (SSDs) linked via USB 3.0 or native SATA (with suitable interfaces). They are the most dependable choice for mission-critical deployments due to their exceptional speed, robustness, and steady data flow.

4.For Educational and Lightweight Office Use: High-quality SD cards, ideally Class 10 or UHS-I, are suitable for low-performance settings with limited budgets, like simple file sharing, data logging, or instructional applications. Because of their price and native compatibility, they continue to be a sensible option even with their limited endurance.

ACKNOWLEDGMENT

I would like to express my sincere gratitude to Dr. Jaymer M. Jayoma for giving me opportunity to work on this research paper under his expert guidance and mentorship. The faith he put in me and the chance to grow and expand my knowledge under his direction is very much appreciated. This experience has not only enriched my academic journey but has also instilled in me a profound sense of inspiration and purpose.

7. REFERENCES

[1]R. Liza, L. Fitriana, J. Junaidi, and D. M. Siddiq, "Cloud Computing Analysis of Hybrid Networks on Raspberry," *Sinkron*, vol. 8, no. 4, pp. 2765–2775, (2023), doi: 10.33395/sinkron.v8i4.13096.

[2]W. Hajji and F. P. Tso, "Understanding the performance of low power raspberry pi cloud for big data," *Electronics (Switzerland)*, vol. 5, no. 2, (2016), doi: 10.3390/electronics5020029.

[3]R. Ritzkal, K. Kodarsyah, A. R. S. Nudin, I. H. Setiadi, F. Riana, and B. Wulandari, "Enhancing Data Storage and Access in CSN Labs with Raspberry Pi 3B+ and Open Media Vault NAS," *Information Dynamics and Applications*, vol. 2, no. 2, pp. 63–76, (2023), doi: 10.56578/ida020202.

[4]R. Thomas Mason and W. K Masters, "Student Learning Using MongoDB Sharding on a Cluster of Ubuntu Raspberry Pi 4B Servers," in *Proceedings of the 2022 InSITE Conference*, Informing Science Institute, (2022), p. 021. doi: 10.28945/4989.

[5]C. Özkurt, "Efficient Server Room Monitoring with Flutterand Firebase - Real-Time Insights and InstantNotifications," Feb. 15, (2024). doi: 10.21203/rs.3.rs-3950749/v1.

[6]S. Maro, A. Kondoro, B. Haßler, J. Mtebe, and J. Proctor, "Deployment of Offline Learning Management Systems: Comparing the Performance of Selected Micro-servers in Tanzania," vol. 10, no. 2, pp. 280–296, (2023).

[7]Raspberry Pi, "Buy a Raspberry Pi 5 – Raspberry Pi," https://www.raspberrypi.com/products/raspberry-pi-5/.

[8]C. Ahmadi, W. Wedashwara, N. N. H. Puspita, and J.-L. Chen, "IoT-Based Smart Village Transaction System Using RFID and Load Cell Modules," in *Proceedings of the First Mandalika International Multi-Conference on Science and Engineering 2022, MIMSE 2022 (Informatics and Computer Science)*, Atlantis Press International BV, (2022) , pp. 341–351. doi: 10.2991/978-94-6463-084-8_29.

[9]R. Ritzkal *et al.*, "Security Vulnerability Analysis and Recommendations for Open Media Vault Cloud Server on Raspberry Pi," *Ingenierie des Systemes d'Information*, vol. 28, no. 3, pp. 711–716,(2024), doi: 10.18280/isi.280321.

[10]H. Yacine and K. Boufeldja, "Wireless internet of things solutions for efficient photovoltaic system monitoring via WiFi networks," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 33, no. 2, pp. 901–910, (2024), doi: 10.11591/ijeecs.v33.i2.pp901-910.

[11]A. Sebastian and K. S. Sankar, "A Secure and Reliable Method to Protect USB Data," *APTIKOM Journal on Computer Science and Information Technologies*, vol. 4, no. 2, pp. 57–60, (2019) , doi: 10.11591/aptikom.j.csit.34.

[12]C. Y. Lu, C. L. Tseng, W. Y. Horng, Y. S. Chiu, C. C. Tai, and T. J. Su, "Applying internet of things to data monitoring of powered wheelchairs," *Sensors and Materials*, vol. 33, no. 6, pp. 1869–1881, (2021), doi: 10.18494/SAM.2021.3247.

[13]U. Saeed, M. A. Khuhro, M. Waqas, and N. Mirbahar, "Comparative analysis of different Operating systems for Raspberry Pi in terms of scheduling, synchronization, and memory management," *Mehran University Research Journal of Engineering and Technology*, vol. 41, no. 3, pp. 113–119, (2022), doi: 10.22581/muet1982.2203.11.

[14]T. M. Alanazi, "Embedded System Based Raspberry Pi 4 for Text Detection and Recognition," *Intelligent Automation and Soft Computing*, vol. 36, no. 3, pp. 3343–3354, (2023), doi: 10.32604/iasc.2023.036411.

[15]N. Damanik, M. R. Robiansyah, A. Apriliana, and S. Purba, "Design of Energy Monitoring System for Small Scale Wind Turbine Applications," in *IOP Conference Series: Earth and Environmental Science*, Institute of Physics Publishing, (2019) . doi: 10.1088/1755-1315/345/1/012003.

[16]O. A. Ibrahim, S. Sciancalepore, G. Oligeri, and R. Di Pietro, "Magneto: Fingerprinting USB Flash Drives via Unintentional Magnetic Emissions," 2020. doi: 10.1145/3422308.

[17]D. A. Ramadhan and R. A. Arrasyid, "Implementation of Live Forensic Method on Fusion Hard Disk Drive (HDD) and Solid State Drive (SSD) RAID 0 Configuration TRIM Features," (2024) .

[18]J. Meza, Q. Wu, S. Kumar, and O. Mutlu, "A Large-Scale Study of Flash Memory Failures in the Field," Association for Computing Machinery (ACM), (2015) , pp. 177–190. doi: 10.1145/2745844.2745848.

[19]H. Yacine and K. Boufeldja, "Wireless internet of things solutions for efficient photovoltaic system monitoring via WiFi networks," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 33, no. 2, pp. 901–910, (2024), doi: 10.11591/ijeecs.v33.i2.pp901-910.

[20]S. Gondi and V. Pratap, "Performance evaluation of offline speech recognition on edge devices," *Electronics (Switzerland)*, vol. 10, no. 21, (2021) , doi: 10.3390/electronics10212697.

[21]I. Ashraf *et al.*, "Home automation using general purpose household electric appliances with Raspberry Pi and commercial smartphone," *PLoS One*, vol. 15, no. 9 (2020), doi: 10.1371/journal.pone.0238480.

[22]S. Guo, “Sports Smart Data Writing Based on New-Type Semiconductor Nonvolatile Storage Mode,” *Sci Program*, (2022) , doi: 10.1155/2022/2770333.

[23]T. Schenk, M. Pešić, S. Slesazeck, U. Schroeder, and T. Mikolajick, “Memory technology-A primer for material scientists,” (2020) , *Institute of Physics Publishing*. doi: 10.1088/1361-6633/ab8f86.

[24]H. Zhang, J. Zhang, and Y. Wang, “Design and Implementation of an Advanced Planning and Scheduling System Based on Microservices,” (2024), pp. 593–601. doi: 10.2991/978-94-6463-262-0_61.

[25] K. Myung Hee, “Transition of Initiative from Ubiquitous City to Sustainable Smart City by Korea: Focusing on the Case of Songdo City”, (2019),pp. 111-115. Doi: https://doi.org/10.15017/2552955

[26] F. Imtiaz, B. Samuil Alam, R. Ashiqur, “Assessment of Thermal performance of Transport Refrigeration Vehicles by Modifications in the Compartment Design and Storage Pattern” , pp. 284-291. Doi: https://doi.org/10.5109/4102504