Designing Data Centre Building Facilities Based on Humidity and Temperature Monitoring System in Hospital Using TIA-942 Standard with PPDIOO Life-Cycle Approach

M. Lubis, A. Widjadjarto, R. R. Fahlevi, S. W. Utomo, A. R. Lubis and Al-Khowarizmi

***Abstract*—Information technology (IT) has been widely applied in various aspects of life, one of them through the IT implementations in hospitals to carry out administrative activities that aim to facilitate data processing and make existing operational activities run more effectively and efficiently. In this case of Muhammadiyah Sumberrejo Islamic Hospital, which requires a server room that is useful as a data center for IT management. It has a long-term plan to develop fair distribution of service in the form of the room heating, ventilation, air conditioning (HVAC) system based on humidity and temperature standard. Thus, it is necessary to design a monitoring system to align with the contextual setting and requirements. In this study, a data center for the Hospital will be designed using the standard of TIA-942 humidity and temperature while the PPDIOO Network Life-Cycle Approach method used for the development process. The result will be in accordance with the HVAC arrangement within the room.**

***Index Terms*— Data Centre, Humidity, Temperature, TIA-942, PPDIOO Life-Cycle Approach**

I. INTRODUCTION

NOWADAYS, Information Technology is currently developing very rapidly in every sector ,impacting on data processing, network services, telecommunications services, and other IT infrastructure, so a data center is required to be able to accommodate all these needs in an efficient way [1-3]. The data center, supposedly a free-standing building, is extremely critical supporting operational activities such as HVAC, lighting, and electricity within the organization [4-5]. It should be designed with a certain specification with the physical room for servers, data storage and networks that fulfilled the requirement and used as a container and control for data processing and management of the entire activity as the heart of the infrastructure [6].

In this case, Muhammadiyah Sumberrejo Islamic Hospital (RSIM Sumberrejo) is a private hospital agency in Bojonegoro [7], accredited and recognized by the government for its good service management and significant contribution to society. Actually, it has implemented many IT application and online approach in carrying out its administrative activities such as the Hospital Management Information System (SIMRS) program along the administration, registration, medical records, emergency room, medicine warehouse, pharmacy, radiology and hospitalization [8].

In fact, to apply the IT approach efficiently and comply with the protective measurement and secrecy attributes, it needs a data center that is useful for storing and processing the data. Actually, at limited used or micro level, the hospital already has a data center but there are many unfulfilled spot that can be improved in various aspects. At macro level, this has resulted that the data center itself have not meet with any standard used either at national and international level, especially related to the critical monitoring process in humidity and temperature system for measurement [9]. The location and size of the data center also did not meet the standards for physical security strategy, which in this case the hospital itself also want to build a new data center room. Then, this study analyzes the requirement in the context to adjust with the budget and environment to allow optimal development of a data center that accommodates every aspect, at least at minimal requirement, which in this case focus on the 8 (eight) aspects of TIA-942 standard namely location determination, raised floor, cooling system, electrical power system power, lighting, security system, monitoring/maintenance system, and fire handling system [10][11].

In this research, the humidity and temperature monitoring system tools also will be applied, which humidity can be defined as the percentage of water in the air that is related highly to the temperature [12]. The lower the temperature generally will increase the humidity value [13]. The tool use in this study, is an Arduino Uno microcontroller and a DHT11

M. Lubis School of Industrial Engineering Telkom university Bandung, Indonesia (email:muharmanlubis@telkomuniversity.ac.id)

A. Widjajarto School of Industrial Engineering Telkom university Bandung, Indonesia (email: adtwjrt@telkomuniversity.ac.id.)

R. R. Fahlevi School of Industrial Engineering Telkom university, Bandung, Indonesia (e-mail: rizalfahlevi@student.telkomuniversity.ac.id)

S. W. Utomo, School of Industrial Engineering, Telkom university, Bandung, Indonesia (e-mail: sandyutomo@student.telkomuniversity.ac.id)

A. R. Lubis, Dept. of Com. Enginnering & Informatics Politeknik Negeri Medan, Medan, Indonesia (e-mail: arifridho@polmed.ac.id)

Al-Khowarizmi, Faculty of Com. Sci. and Inf. Technology Universitas Muhammadiyah Sumatera Utara, Medan, Indonesia (e-mail: alkhowarizmi@umsu.ac.id)

sensor [14]. Suppose the humidity and temperature are less or exceed the predetermined standards. In that case, it will be seen on the tool in the real-time [15], which of course, the monitoring process also can be seen on the website or other network application that implement packet switching [16]. This data later on, will be used for further analysis and calculation for making the decision in the data center room [17]. Thus, the primary purpose of this study is to investigate a data center room design that is in accordance with the TIA-942 standard to be applied at the respective hospital with the PPDIOO life-cycle approach.

II. Literature Review

According to the Telecommunication Industry Association (TIA-942) [18], the definition of a data centre is a building or part of that has the main function for controlling and managing network within the organization and its supporting area. It can be said that it is to consolidate and centralize every IT resource, network operating houses, facilitating electronic business and transaction to provide uninterrupted services for critical data processing. In fact, it has five main service aspects as mentioned [19], which are business continuity infrastructure that contains any aspects related to the continuity of business processes when the data centre is in a critical condition. These aspects include choosing the location of the data centre, setting the layout in the data centre room, the required electrical system, controlling the cooling system, and controlling fire management, which must be maintained.

Secondly, data centre security should consists of physical and non-physical security systems, which include user access to the data centre in the form of access key to enter the room or even biometric and all security officers who oversee the state of the data centre, either inside or outside. Meanwhile, non-physical security is carried out on the part of the software or system that runs on devices within the data centre, among others by installing software such as firewalls and access control lists, layer 2 (data link layer) security features such as VLAN and port security and layer 3 (network) such as IP configuration. Thirdly, application optimization at layer 4 (transport layer) and layer 5 (session layer) to increase the response time of a server. Layer 4 is the lowest layer between the application and the process of sending data to the destination, while layer 5 is the layer that determines who is sending a packet or receiving a packet and determine on how the status of the packet is sent. In relation to the technology aspect, load balancing is also used to optimize the running of applications with the faster the response time required, the better the optimization.

Fourthly, IP infrastructure, which is the data centre's main service, should be monitored rigorously. At layer 2, the IP infrastructure aspect relates to the relationship between the server farms and the devices that access them, allowing connectivity to the other media and channel to support reliable centralization. If a problem occurs in the IP infrastructure, the accessibility will be disrupted. Lastly, storage infrastructure that includes the types of storage media that will be implemented in the data centre as needed. For example, using the Storage Area Network (SAN) architecture and fibre channel switching for storage infrastructure so that there is segment separation between servers that accommodate main services and storage media. It also requires a backup to anticipate an unexpected event to prevent data loss on the storage media.

TIA-942 is an international standard issued in America that regulates and determines the minimum requirements in building telecommunications infrastructure from data centres and computer rooms including data centres owned by a company or a data centre used by more than one company [20]. It is a non-profit institution that is accredited and supervised by ANSI while the certification standard is carried out by certain organization such as Enterprise Product Integration (EPI) which claims to be the first and only authorized training and certification institution or Conformity Assessment Body (CAB) under the official TIA-942 accreditation scheme [21]. The topology proposed in this standard is intended to be applicable to various sizes of data centres. Meanwhile, the aspects that become references include location, access, architectural design, environmental design, electrical design, fire protection, and water infiltration [22].

The HVAC (Heating, Ventilation, Air Conditioning) system is an air conditioning facility that is used to control the ambient temperature of the data centre [23]. It has an important role in its use in data centres, which meet computer equipment that needs to be kept in air humidity requires a good ventilation system. The following is a detailed explanation of HVAC [24], which are heating used in areas that have a predominantly cold season. There are important parts that are arranged in heating, including a boiler, furnace, heat pump, and hydronic. Furnace is a heat source sent to a water medium called hydronic in the boiler. Hydronic circulates thanks to the work of the heat pump, after the boiler, hydronic goes to the radiator to transfer the heat, which contained into circulated air used to heat the room. Then, ventilation, which is the process of circulating the air in a room with outdoor air, aims to remove dust, moisture, unpleasant odours, carbon dioxide, heat, bacteria and regenerate oxygen in the room. Meanwhile, ventilation is an application of fluid mechanics theory, which has two types: forced and natural ventilation. Forced ventilation is a system that uses a fan to circulate air in the room and is widely used in large industries and buildings. Natural ventilation does not require the help of a fan to circulate air. Usually, just a window left open in a room. Next, air conditioner that uses the principle of a cooling engine cycle which consists of the essential parts, namely the refrigerant, compressor, heat exchanger and expansion valve. There is a difference between air conditioning used in homes and air conditioning used in office buildings and industrial buildings. The difference is using a medium called Liquid Chiller. The way it works is that circulated air is absorbed by heat through a heat exchanger by a liquid chiller in one component called the Air Handling Unit (AHU).

Actually, the heat from the liquid chiller is absorbed by the

refrigerant through another heat exchanger. That is why liquid chiller is used in air conditioners in large buildings because the air circulation in the building has a large volume and it will be more efficient. For the humidity, the concentration of water vapor in the air, which its number can be expressed in terms of absolute humidity, specific humidity, or relative humidity. The relative humidity is a term used to describe water vapor contained in the water-air mixture in the gas phase while the temperature is a measure of the state of the object which determines the speed at which the object receives or releases heat to its surroundings which are different from that of the object. Meanwhile, Network Development Life Cycle (NDLC) is a strategy to develop infrastructure and network systems in a company, organization, or agency [25-26]. It is the development of a system that can be called the System Development Life Cycle (SDLC) due to its similarity, which in this case to develop server room. Meanwhile, PPDIOO is an analysis method to check the development process of computer network installations developed by Cisco on the Material Designing for Cisco Internetwork Solution (DESGN) with the service life cycle required for the development of computer networks or related technologies. With the development of increasingly sophisticated technologies, these companies compete to leverage technology to gain a competitive advantage and an efficient performance over their competitors [27]. Therefore, mere adoption of standards is not sufficient, because differences in organizational culture, employee patterns, work commitments and budgetary constraints have an absolute impact on the level of results that the company will have in the short and long term [28-30].

III. EXISTING CONDITION OF DATA CENTRE

The data center at the Muhammadiyah Sumberrejo Islamic Hospital consists of one room on the second floor. It is in the primary building of the Hospital that include CCTV control, management room and network control. The hospital's data center has inadequate infrastructure because it only has a building area of 3.3 meters x 2.2 meters. Besides that, the racks used to store servers are made of wood and the cabling system is not neatly arranged, making it difficult to loosen or track if a problem occurred. On the other hand, there is no raised floor in the data center where only several and limited devices are used to support the process and operation that data center activities conducted as in the following table 1. On the other hand, the air conditioner (AC) is one of the devices used in HVAC systems where its main function is to keep the room temperature in the data center for stable condition, which the specification can be seen in table I and II.

TABLE I
DATA CENTRE DEVICES

No.	Device Name	Amount
	Server Rack	
1.	Inverter	1
2.	Router	2
3.	Server	5
4.	Computer	1
	Beside Rack Server	
5.	Accumulator	2
6.	Power Supply	1
7.	Thermometer	1
8.	Daily temperature log board	1
	B3 Table	
9.	Computer	1
10.	Network DVR	1
11.	CCTV Control	1
	Above B1 Table	
12.	PABX	1
13.	PABX Cabling	1
	Room	
14.	Air Conditioner	1
	Total	24

TABLE II
DATA AIR CONDITIONERS

No.	Device Name	Brand and Type	Capacity
1.	Air Conditioner	Panasonic CS YN 7 SKJ	¾ PK

The air conditioner capacity within the data center room should meet the standard requirement where its capacity based on PK as the following list in the formula 1 below. Meanwhile, the calculations according to the conditions and requirement from the Sumberrejo Hospital data center can be seen in formula 2.

$$\begin{aligned} \text{AC } \tfrac{1}{2}\text{ PK} &= \pm 5.000\ \text{BTU/h} \\ \text{AC } \tfrac{3}{4}\text{ PK} &= \pm 7.000\ \text{BTU/h} \\ \text{AC1 PK} &= \pm 9.000\ \text{BTU/h} \\ \text{AC 1}\tfrac{1}{2}\text{ PK} &= \pm 12.000\ \text{BTU/h} \\ \text{AC 2 PK} &= \pm 18.000\ \text{BTU/h} \end{aligned} \quad (1)$$

$$(\text{L} \times \text{W} \times \text{H} \times \text{I} \times \text{E})/60 = \text{BTU Needs}$$

L = Room Long (in feet)
W = Room Wide (in feet)
I = value of 10 if the room is insulated (located on the lower floor, or coincided with another room) while value of 18 if the room is not insulated (upstairs)
H = Room Tall (in feet)
E = value of 16 if the longest wall faces north, or value of 17 if faces east, or value of 18 if faces south or value of 20 if faces west, which 1 Meter equal to 3.28 feet.

$$\begin{aligned} &(3.312)\,(3.28) \text{ x } (2.213)\,(3.28) \text{ x } (2.52)\,(3.28) \\ &\text{x } (18) \text{ x } (18) / 60 \\ &= \text{BTU Needs} \\ &((10.86) \text{ x } (7.25) \text{ x } (8.26) \text{ x } (18) \text{ x } (18)) / 60 \\ &= \text{BTU Needs} \\ &(210{,}713.7564) / 60 = \text{BTU Needs} \\ &3{,}511.8959 = \text{BTU Needs} \end{aligned} \quad (2)$$

The calculations showed that the required capacity for an air conditioner in the data center room is 3,511.8959 BTU, equivalent to ½ PK. Meanwhile, the air conditioner used in the data center has a capacity of ¾ PK. This is inefficient because there has been a waste in the use of air conditioner that should use a smaller PK. The temperature at the data center must

meet the standards according to TIA-942 which is aligned with ASHRAE; it is 18˚C - 27˚C. In the current condition, the RSIM Sumberrejo data center has an average room temperature of 24˚C while it has no humidity measuring device. Therefore, this study wants to implement the design for a humidity monitoring system made of an Arduino Uno microcontroller, which is connected to the website or online approach to allow the relevant employee look at the monitoring results anywhere and anytime. The following table III is a gap analysis of the current condition of the data center at RSIM Sumberrejo with the TIA-942 - A (2012) mechanical Tier 2 standard on HVAC. It showed that the data center located at the Muhammadiyah Sumberrejo Islamic Hospital has not met the TIA-942 Tier 2 Standard because of the 10 assessment points only 10% have been fulfilled. Thus, many things must be added if the Sumberrejo Hospital data center wants to comply with the TIA-942 Tier 2 standard.

TABLE III
GAP ANALYSIS OF EXISTING CONDITION WITH TIA-942 TIER 2

Parameter	TIA-942 Tier 2	Existing Cond.	Check list
	Data Centre Celling Room		
Ceiling height	2,6 m minimum	2,52 m	X
	Structural		
Raised floor	Using raised floor	Not using raised floor	X
	Mechanical General		
Redundant for mechanical tools (ex: air conditioning units, coolers, pumps, cooling towers, condensers)	N + 1 redundant for mechanical tool. Loss of electrical power can result in loss of the cooling system	There is no N + 1 redundant	X
Floor drain in computer room to condensate drain water, humidifier flush water, and sprinkler discharge water	Yes	There is no floor drain	X
Mechanical systems on standby generator	Yes	There is no standby generator	X
	Air-Cooled System		
Electrical Service to Mechanical Equipment	Single path of main power to AC equipment	There is no single path of main power to AC equipment	X
Temperature Monitoring System for Computer Room	Having Temperature Monitoring System Tools	Just using wall-hanging Thermometer	X
Temperature and Humidity Control for Computer Room	Having Humidification Tools	Using an Air Conditioner Split	√
	HVAC Control System		
HVAC Control System	A control system failure will not interfere with cooling to critical areas	There is no HVAC control	X
Power Source to HVAC Control System	Redundant, UPS electrical power to BMS control	Only use one common power supply without redundant	X
	Result		
Points that must be met	10	Points are fulfilled	1

IV. PROPOSED LAYOUT AND SYSTEM

Based on the results of the gap analysis of the current conditions with the TIA-942 standard, there are components that must be added so that the data centre conforms to the Tier 2 standard of TIA-942. In this proposed layout, there is a list of equipment that must exist as seen in the following table 4. The proposed data center layout at the Muhammadiyah Sumberrejo Islamic Hospital in accordance with the TIER 2 TIA-942 standard uses a room size of 8x10 meters with a height of 2.6 meters. The proposed TIER 2 layout already has redundancy requirements (N + 1) on the UPS and HVAC equipment. The proposed air conditioning system uses two UPS, two HVAC, and one split AC based on the proposed AC capacity requirements.

TABLE IV
PROPOSED DEVICES LIST

No.	Device Name	Amount
1.	Server Rack	4
2.	Battery	2
3.	HVAC	2
4.	Humidity Monitoring System	1
5.	Temperature Monitoring System	1
6.	AC Split	1
7.	Personal Computer	2
8.	Network DVR	1
9.	CCTV Control	1
10.	PABX	1
11.	PABX Cabling	1
12.	Generator	1
13.	UPS	2
14.	Main Distribution Panel	1
15.	Automatic Transfer Switch	1
16.	Exhaust Fan	2
17.	Monitor	1
18.	Server Tower	4
19.	Server	4
20.	Core Switch	4
21.	Core Router	4
22.	Power Distribution Unit	2
	Total	43

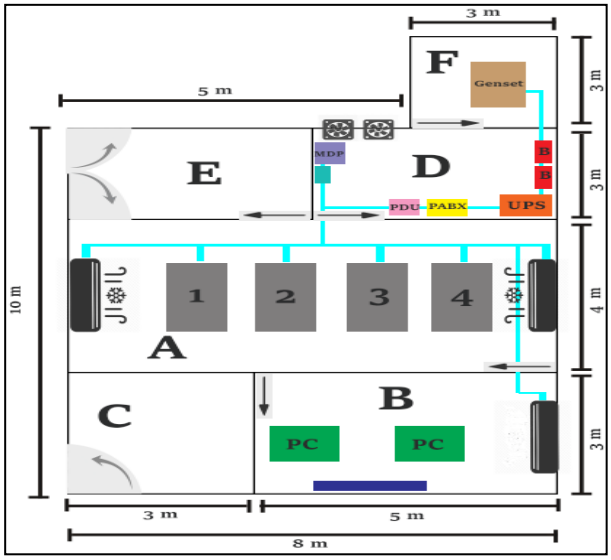

Fig. 1. Propoed Data Centre Layout

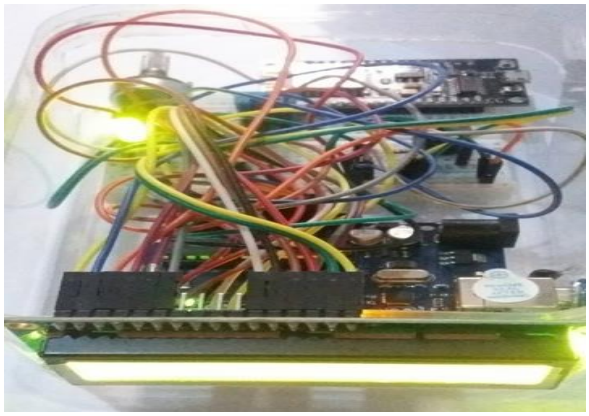

Fig. 2. Proposed Humidity and Temperature Monitoring Tool

Based on the figure 1 above, there are 2 UPS and HVAC, one of which is useful as a backup to match the TIER 2 requirements that must be a single path of power and cooling with redundancy (N + 1). Humidity Monitoring System is a tool that measures a room's humidity level. Humidity can be defined as the concentration of water vapor in the air, keeping humidity in normal conditions serves to prevent corrosion of some devices in the data center due to evaporation or to prevent the appearance of electrostatics on some metal devices. The recommended humidity for a data center room is around 40% - 50%. Humidity level gauges should be placed in the vicinity of the device because they can immediately track the humidity level around the device.

Based on the results of the current condition gap analysis with the TIA-942 standard, a temperature monitoring system is required to be applied to a data center. The temperature monitoring system is part of environmental monitoring which is one of the main aspects of the data center. The main function of the temperature monitoring system is to measure the heat generated by the equipment, and at the intake and exit vents of the air conditioning system to measure efficiency.

The temperature monitoring system should be located in the vicinity of critical equipment, as the temperature inside the equipment on a shelf can be up to 20 degrees higher than the surrounding area. Controlling the state of the data center room temperature to stay awake in a stable condition according to the TIA-942 standard, which is 18 Celsius degrees to 25 Celsius degrees and at Tier 2 should use the best temperature, which is 18 degrees Celsius. With the stable temperature conditions, the server performance will be maximized while the proposed tool can be seen in figure 3. The tool in this study, made of an Arduino Uno microcontroller uses a DHT11 sensor to measure humidity and temperature. With this tool, the humidity and temperature in the data center room can be monitored through the LED monitor screen on the device then the Thingspeak.com web, which can be seen in figure 5, as the reference used will be able to store and monitor the data.

Fig. 3. ThinkSpeak.com Monitoring Screen

In this case, an Arduino Uno microcontroller has been used with DHT11 sensor to measure humidity and temperature. With this tool, the condition in the data center room can be monitored through the LED monitor screen on the device then the Thingspeak web as can be seen in figure 4, which in this case become the reference used will be able to store and monitor the data. Furthermore, before determining on how much UPS capacity is needed, it should analyze the total power usage or wattage of devices in each rack and HVAC system. The results of the analysis showed that the total power usage is 15300 watts. The power generated from the UPS voltage needs to have a power range 25% greater than the required power. If the load is 15300 watts, the power generated 25% is greater, which is 19125 watts. While choosing how many VA UPS is needed, it is important to know that this UPS's power value (W) is 60% of the rated voltage (VA). From the known power of 19125 watts, the voltage value is 31.875 kVA. With the required VA, the UPS that can be selected is the UPS with a voltage of 40 kVA.

In this case, a raised floor is needed because there is no cooling system under the floor and a good cabling system. It is a tile-shaped stage with a size that has been adjusted to the TIA-942 standard to elevate the data center room. The space under the tiles can be used for the cooling system by going through the aisle near the server rack. In addition to the cooling system, the raised floor can also be used for cabling installations so that the cables in the RSIM Sumberrejo data center are arranged according to TIA-942. Thus, the cabling system uses a single path of power and cooling according to Tier 2. The path for HVAC devices and servers has its own path, different from the path used by electrical equipment. Interestingly, consumer interest in the product is recognized after purchasing and evaluated, which is often favored through Internet feedback [31-34].

V. CONCLUSION

The data center at RSIM Sumberrejo is not in accordance

with an existing standard. The components in TIER 2 have not been fulfilled because the data center does not have a room humidity meter, does not have a generator, does not have a raised floor does not have a Computer Room Air Conditioning. There is no good humidity dan temperature handling because it does not have a humidity and temperature monitoring system in the data center room. After doing research and knowing the existing conditions that do not meet the standards, it is proposed to create humidity and temperature monitoring system for use in the Sumberrejo Hospital data center which made of the Arduino Uno microcontroller which can be seen directly through the screen on the microcontroller, the results can also be seen via the ThingSpeak web. The humidity and temperature monitoring system tool are placed near the server so that the results obtained are more accurate for the device.

REFERENCES

[1] K. Rabah, "Convergence of AI, IoT, big data and blockchain: a review," *Lake Inst. J.*, vol. 1, no. 1, pp. 1–18, 2018.

[2] F.S.D. Silva et all, "Necos project: Towards lightweight slicing of cloud federated infrastructures," in *2018 4th IEEE Conference on Network Softwarization and Workshops (NetSoft)*, 2018, pp. 406–414.

[3] A. Beloglazov, J. Abawajy, and R. Buyya, "Energy-aware resource allocation heuristics for efficient management of data centres for cloud computing," *Futur. Gener. Comput. Syst.*, vol. 28, no. 5, pp. 755–768, 2012.

[4] M.R. Alkasisbeh, "An Integrated Decision Support Framework for Life-Cycle Building Asset Management," Ph.D Dissertation, Western Michigan University, 2018.

[5] S. Nižetić, P. Šolić, D. L.-I. González-de, and L. Patrono, "Internet of Things (IoT): Opportunities, issues and challenges towards a smart and sustainable future," *J. Clean. Prod.*, vol. 274, p. 122877, 2020.

[6] S.K. Uzaman, J. Shuja, T. Maqsood, F. Rehman, and S. Mustafa, "A systems overview of commercial data centres: initial energy and cost analysis," *Int. J. Inf. Technol. Web Eng.*, vol. 14, no. 1, pp. 42–65, 2019.

[7] D.A. Sofiyana and E. Yusuf, "Hubungan kualitas pelayanan perawat dengan kepuasan klien di ruang rawat inap marwah Rumah Sakit Islam Muhammadiyah Sumberrejo Bojonegoro," *J. Hosp. Sci.*, vol. 1, no. 1, 2017.

[8] Z. Siti, S. Sudalhar, and T.W.Y. Pratama, "Pengaruh kualitas pelayanan pada bagian penerimaan pendaftaran pasien rawat jalan terhadap kepuasan pasien rawat jalan di Rumah Sakit Islam Muhammadiyah Sumberrejo," *J. Hosp. Sci.*, vol. 4, no. 1, pp. 121–128, 2020.

[9] G. Rosace, V. Trovato, C. Colleoni, M. Caldara, V. Re, M. Brucale, E. Piperopoulos, E. Mastronardo, C. Milone, G.D. Luca and M.R. Plutino, "Structural and morphological characterizations of MWCNTs hybrid coating onto cotton fabric as potential humidity and temperature wearable sensor," *Sensors Actuators B Chem.*, vol. 252, pp. 428–439, 2017.

[10] J. Wan, X. Gui, S. Kasahara, Y. Zhang, and R. Zhang, "Air flow measurement and management for improving cooling and energy efficiency in raised-floor data centres: A survey," *IEEE Access*, vol. 6, pp. 48867–48901, 2018.

[11] A.T. So and W. L. Chan, *The Future of Intelligent Building Systems. In:* Intelligent Building System, The International Series on Asian Studies in Computer and Information Sc. vol. 5. Springer Science & Business Media, 2012.

[12] P. Wolkoff, "Indoor air humidity, air quality, and health–An overview," *Int. J. Hyg. Environ. Health*, vol. 221, no. 3, pp. 376–390, 2018.

[13] A.J. Prussin, D.O. Schwake, K. Lin, D.L. Gallagher, L. Buttling, and L. C. Marr, "Survival of the enveloped virus Phi6 in droplets as a function of relative humidity, absolute humidity, and temperature," *Appl. Environ. Microbiol.*, vol. 84, no. 12, 2018.

[14] P. Bhadani and V. Vashisht, "Soil moisture, temperature and humidity measurement using arduino," in *2019 9th Int. Con on Cloud Computing, Data Science & Engineering (Confluence)*, 2019, pp. 567–571.

[15] M. Valinejadshoubi, O. Moselhi, A. Bagchi, and A. Salem, "Development of an IoT and BIM-based automated alert system for thermal comfort monitoring in buildings," *Sustain. Cities Soc.*, vol. 66, p. 102602, 2021.

[16] M.S. Mahdavinejad, M. Rezvan, M. Barekatain, P. Adibi, P. Barnaghi, and A.P. Sheth, "Machine learning for Internet of Things data analysis: A survey," *Digit. Commun. Networks*, vol. 4, no. 3, pp. 161–175, 2018.

[17] M. Avgerinou, P. Bertoldi, and L. Castellazzi, "Trends in data centre energy consumption under the european code of conduct for data centre energy efficiency," *Energies*, vol. 10, no. 10, p. 1470, 2017.

[18] H. Ye, Z. Song, and Q. Sun, "Design of green data centre deployment model based on cloud computing and TIA942 heat dissipation standard," in *2014 IEEE Workshop on Electronics, Computer and Applications*, pp. 433–437, 2014.

[19] T.M. Shahrani, A.N. Ramdhania, and M. Lubis, "Implementation of Building Construction and Environment Control for Data Centre Based on ANSI/TIA-942 in Networking Content Company," in *Journal of Physics: Conference Series*, 2019, vol. 1361, no. 1, p. 12074.

[20] S.S. Hermawan and R.R. Saedudin, "Design of Cooling and Air Flow System Using NDLC Method Based on TIA-942 Standards in Data Centre at CV Media Smart Semarang," *Int. J. Adv. Data Inf. Syst.*, vol. 1, no. 1, pp. 34–39, 2020.

[21] M. A. Pratama and M. T. Kurniawan, "Design And Analysis Physical And Logical Security Using TIA-942 And ISO/IEC 27000 Series In Data Centre Of PDII-LIPI," 2016.

[22] A.A.W. Fatimah, M.T. Kurniawan, and U.Y.K.S. Hediyanto, "Network Traffic Data Centre Based on TIA-942 Standard: A Case Study in Bogor Government Office," *J. Adv. Comput. Networks*, vol. 8, no. 1, 2020.

[23] I.-S. Suh, M. Lee, J. Kim, S. T. Oh, and J.-P. Won, "Design and experimental analysis of an efficient HVAC (heating, ventilation, air-conditioning) system on an electric bus with dynamic on-road wireless charging," *Energy*, vol. 81, pp. 262–273, 2015.

[24] X. Wei, A. Kusiak, M. Li, F. Tang, and Y. Zeng, "Multi-objective optimization of the HVAC (heating, ventilation, and air conditioning) system performance," *Energy*, vol. 83, pp. 294–306, 2015.

[25] J.E. Goldman and P. T. Rawles, "Applied Data,"*Commun. A Business-Oriented Approach. USA Purdue Univ.*, 2001.

[26] A. Widjajarto, M. Lubis and M.K.R. Syahputra, "Optimization Performance Management with FCAPS and ITILv3: Opportunities and Obstacles." *IJEECS*, vol. 17, no. 1, pp. 281-290, 2020.

[27] T. Syafiera, M. Lubis, R.W. Witjaksono and H.D. Anggana, "The Means of Engagement (MOE) Model of the Agreement towards the Enterprise Resource Planning (ERP) Implementation." *IEEE ICIC* 2019.

[28] J.M. Shahrani, A.N. Ramdhania and M. Lubis, "Implementation of Building COnstruction and Environment Control for Data Centre based on ANSI/TIA-942 in Networking Content Company." *J. of Physics: Conf. Series* 1361:012074, 2019.

[29] F. Lubis and M. Lubis, "Network Fault Effectiveness and Implementation at Service Industry in Indonesia." *J. of Physics: Conf. Series* 1566: 012080, 2020.

[30] M. Lubis, R. Fauzi, A.R. Lubis and R. Fauzi, "A Case Study of Universities Dormitory Residence Management System (DRMS) in Indonesia." *IEEE CITSM* 2018.

[31] J.N. Sari, L.E. Nugroho, P.I. Santoso and R. Ferdiana, "The Measurement of Consumer Interest and Prediction of Product Selection in E-Commerce using Eye Tracking Method." *Int. J. of Intelligent Engineering & System* vol. 11, no. 1, pp. 30-40, 2017.

[32] K. Kaliyan and R. Kothandaraman, "Secure Decision-Making Approach to Improve Knowledge Management based on Online Sample." *Int. J. of Intelligent Engineering & System* vol. 11(1), pp. 50-61, 2017.

[33] M. Lubis, M. Kartiwi and S. Zulhuda, "Current State of Personal Data Protection in Electronic Voting: Criteria and Indicator for Effective Implementation," *Telkomnika*, vol. 16, no. 1, pp. 290–301, 2018.

[34] M. Lubis, A.R Lubis, B. Lubis and A. Lubis, "Incremental Innovation towards Business Performance: Data Management Challenges in Healthcare Industry in Indonesia," *MATEC Web of Conferences*, 218, 04015, 2018.