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Integrated information system development planning at tropical biopharmaca research center using enterprise architecture planning

Larasati[1] and Wisnu Ananta Kusuma[1,2*]

[1]Departement of Computer Science, IPB University, Bogor 16680, Indonesia
[2]Trophical Biopharmaca Research Centre, IPB University, Bogor, 16128, Indonesia

*E-mail: ananta@apps.ipb.ac.id

Abstract. Tropical Biopharmaca Research Center (Trop BRC) of Bogor Agricultural University (IPB) is a national research center that has the vision to become an international standard research center. To achieve this vision, Trop BRC IPB has to improve its quality of all aspects, such as by developing an integrated information system. Trop BRC IPB requires an integrated information system to manage its research activities and enterprise data more effectively. This study aims to define the architecture requirement that supports Trop BRC IPB's business process and to guide the development of an information system using Enterprise Architecture Planning (EAP) method and Zachman framework. This study is conducted in the following stages, including preliminary planning, review of an existing enterprise, architectural design, and implementation planning. The results of this study are represented on tables, matrices, and diagrams that define the needs of data architecture, applications, and technology which can be used as a blueprint for applications developer team of Trop BRC IPB to develop and implement an integrated information system.

1. Introduction

Trop BRC IPB is a research center established by IPB University in 1998 based on the SK Rektor No. 118 / K13 / HK / OT / 1998. It has been awarded as one of the best national research centers by the Indonesian Ministry of Research and Technology. The main focus of Trop BRC IPB is conducting research on plants, animals, minerals and microbes which potential to produce healthy medicines and foods for humans, animals, and plants. Trop BRC IPB has the vision to become the best biopharmaceutical research center in national and international scope. It also has the vision to become an international standard research center. To achieve those visions Trop BRC IPB must improve its quality in various aspects, such as improving the quality of work programs and human resources, increasing the efficiency of business processes, and increasing technology utilization. Information technology is one of the technologies that should be utilized by Trop BRC IPB.

Information technology (IT) is a technology used to process data as well as to produce relevant, accurate, and strategic information for decision making. IT could be used for various purposes such as to support business processes at the research center [9]. The application of information technology itself is a long-term investment for organizations and companies in order to improve the effectiveness of their business processes. Trop BRC IPB has not optimally implemented IT yet, either in research activities or in organizational management activities. The business process of Trop BRC IPB is quite a

lot and complex. Therefore, Trop BRC IPB needs to increase the utilization of information technology to support its business processes.

One of the most suitable IT that could be applied by Trop BRC IPB is an integrated information system. An integrated information system can help streamline the Trop BRC IPB business process by involving various organizational functional units and preventing duplication of data among information systems. The ideal development of an integrated information system should be planned carefully so that the development is in the right direction and systematic.

Integrated information system development planning can be conducted using an enterprise architecture framework, such as TOGAF, IAF, and Zachman. Enterprise architecture can describe the basic infrastructure of an organization as a basis for configuring hardware, software, and networks to obtain the organization goal. Enterprise architecture can connect the vision, mission, and goals of the organization with the technical or information technology infrastructure required to assist business processes [5]. Zachman's framework is one of the enterprise architecture frameworks that is quite often employed because it uses non-technical and tabular language that make it easy to understand. Zachman's framework encompasses aspects of enterprise architecture making it easier for users to focus on certain aspects of an object without losing contextual or holistic perspectives.

One of the methods that could be used to generate an information system development plan is Enterprise Architecture Planning (EAP). EAP is the process of defining an organizational architecture for information utilization in supporting business process and its plan for implementing the architecture. EAP could be used to define architectural planning to provide data quality, access to data, and adaptability to change [3]. Planning information system development using EAP accompanied by Zachman's framework can provide guidance on what aspects EAP wants to be defined so that the planning result becomes more systematic and could yield information system development architecture that meets organization’s needs.

There were some previous studies related to the use of Zachman's framework and EAP on conducting information system development planning such as the development of institutional governance system design of the Faculty of Mathematics and Natural Sciences IPB [1]. The result of this study is the recommendation of information system modules along with the estimated time and human resources which are required for the implementation. The estimated time and human resources were calculated using function point technique. A similar study was also conducted by [8] with a case study of a tourism destination recommendation system. Moreover, [6] conducted research that succeeded in creating a blueprint for supporting the business function of the Bogor Milk Production Cooperative with the result of the application development priority recommendations using Analytical Hierarchy Process (AHP). In this study, we used the EAP method and Zachman framework for developing an information system master plan for Trop BRC IPB.

2. Materials

Data used in this research was obtained by conducted some activities such as studying the literature of ISO: 9001 documentation which contains operational standards and work procedures at Trop BRC IPB, conducting literature study on organizational management report documents of the Trop BRC IPB, direct observations of related organizations conditions to study current business process implementation, and interviews some employees of each Trop BRC IPB organizational unit regarding the current business processes and the obstacles faced.

3. Methods

This study refers to the EAP method with Zachman framework (Figure 1) as follows.

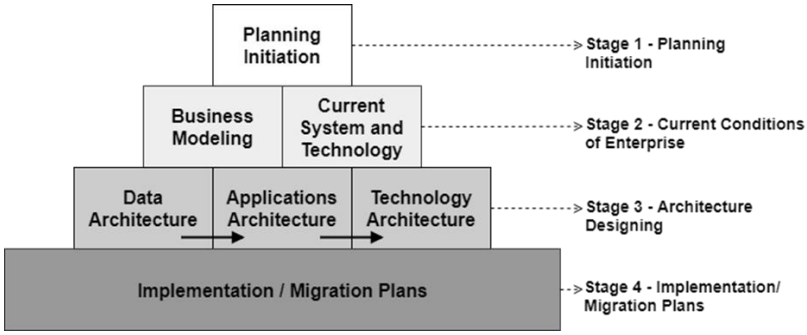

Figure 1. Stages of EAP.

3.1. Planning Initiation

The first stage(planning initialization) is carried to prepare the requirements to start the core of EAP activities. This phase includes identifying the regulations applied by Trop BRC IPB. This regulation is required to define the scope of the enterprise, whether the analysis and planning cover the entire organizations or a few parts. The next activity is to analyze the Trop BRC IPB vision and mission.

3.2. Understanding Current Conditions of Enterprise

This stage is crucial to understand the enterprise architecture, enterprise business functions, and the systems and technologies adopted in the enterprise. This stage includes as follow:

- Business modeling. This step consists of identifying the Trop BRC IPB organizational structure, identifying business functions in Trop BRC IPB using the value chain model, decomposing business functions, and correlating business functions to organizational units.
- Observation of current systems and technologies. This step aims to identify the technology used by the Trop BRC IPB by collecting data from the division of facilities and properties.

3.3. Designing Architecture

This stage is conducted to identify and design data architecture, application architecture, and technology architecture.

3.3.1. Data Architecture. In this step, we determined entities related to the Trop BRC IPB business function by creating a data entity list. This stage also defines the relationships between entities to entities and the relationship between entities to Trop BRC IPB business function which is represented by entity relation diagrams and domain model class diagram.

Applications Architecture. Application architecture is conducted after data architecture stage. These steps consist of making a list of potential information systems and their definitions, creating a matrix of information system candidate relationships with business functions and organizational units, use case diagrams, sequence diagrams, as well as analyzing the impact of planned information system implementation.

3.3.2. Technology Architecture. This stage defines the technology platform needed to support the implementation of information systems and manage data that has been defined previously. In this study, we defined data flow and processes involved in Trop BRC IPB, identifying technology principles and platforms used, defining technology platforms, defining the relationship of technology platforms with the Trop BRC IPB business functions and applications.

3.4. Implementation/Migrations Plans

The implementation plans consist of three steps: determining priorities for developing information system recommendations using Analytical Hierarchy Process (AHP), estimating time and costs using Function Point Analysis (FPA), and determining migration strategies for acquisition of technology platforms.

4. Results and Discussion

4.1. Planning Initiation

Scope of Enterprise. The scope of Trop BRC IPB activities based on Trop BRC IPB standard operating procedure and interview on Trop BRC IPB employees are:

- Managing research activities in the biopharmaceutical field where the results can be used by the wider community (in the form of products or scientific journal publications).
- Conduct activities in the field of education through a workshop in the biopharmaceutical field.
- Conduct community service through biopharmaceutical training activities in various regions in Indonesia.
- Providing research services and biopharmaceutical products for the community.
- Has an employee management system as well as Trop BRC IPB infrastructure facilities that support all Trop BRC IPB activities.
- Has an administration system and quality assurance system.

Vision and Mission of Enterprise. The vision of Trop BRC IPB is to be a leading research center in biopharma areas through optimizing the added value of natural resources both at national and international level.. While the mission of Trop BRC IPB includes:

- To support capacity building through education, training, and community services.
- To assemble, to synergize, and to increase cooperation and networking amongst human resources within units in IPB as well as outside IPB in materializing the enhancement of biodiversity values that have biopharmaca prospects.
- To develop science, technology, and arts based on advanced research with outputs of science and technology, potency, and biopharmaca products that fulfill patent requirements and intellectual-property-rights oriented, which can support the self-sustained nation.

4.2. Understanding Current Conditions of Enterprise

4.2.1. Current Business Modeling. At this stage, defining and identifying business functions in Trop BRC IPB is done using the value chain model. The value chain model divides each enterprise business function into two categories, namely primary activities and support activities. Primary activities are business functions that are the main objectives of the enterprise, while support activities are business functions carried out by enterprises to support the implementation of primary activities. Based on the scope, vision, mission, and organizational structure of the Trop BRC IPB, business functions as shown in Figure 2 are obtained.

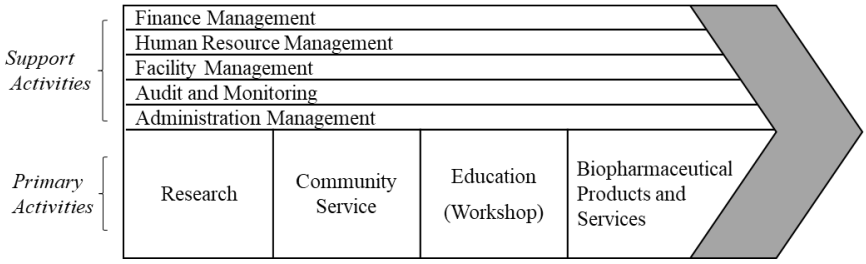

Figure 2. The value chain model of Trop BRC IPB.

After all business functions have been identified through the value chain business model, the next step is to make the decomposition of the business functions. The decomposition results referred as business activities. The results of defining the business functions above will then be made a resource cycle model to clarify the decomposition of business functions into business activities. The decomposition will also be mapped with related organizational units in the business function relations matrix of organizational units. The matrix functions to find out which organizational units have responsibilities and tasks in carrying out a business function. This is done to provide a knowledge base that can be used to define architectural plans.

4.2.2. Current System and Technology. The next step is to identify the current technology systems and platforms used at the Trop BRC IPB. List of system and technology used by the enterprise were obtained from direct observation and interviews with facilities and properties division staff at Trop BRC IPB (Table 1).

Table 1. Trop BRC IPB current system and technology.

Organizational Unit	Storage	Operating System	Software	Communication	Supporting Device
Secretariat	500GB Internal HDD, server	Windows 10	Microsoft office, Corel draw, adobe photoshop, nitro pro pdf, google chrome	Telephone, USB Wifi, LAN	Printer
UIH	500GB Internal HDD	Windows 10	Microsoft office, adobe photoshop, google chrome	USB Wifi	Printer
UPPW	500GB Internal HDD	Windows 10	Microsoft office, google chrome	Wifi	Printer
LAB Trop BRC	500GB Internal HDD	Windows 10	Microsoft office, google chrome, spss	USB Wifi, LAN	Printer
UKBB	500GB Internal HDD	Windows 7	Microsoft office, web browser chrome/Mozilla	Wifi	-

4.3. Designing Architecture

4.3.1. Data Architecture. This step will identify Trop BRC IPB's business entities and data entities. The identification results of business entities candidates and data entities can be seen in Table 2. Data architecture is also identified to support the management of existing data entities (Figure 3). Users who in this case include Trop BRC IPB employees, students, and the general public, can store or retrieve data stored in the database. The database stores data and documents inputted by users on Trop BRC IPB and cloud servers.

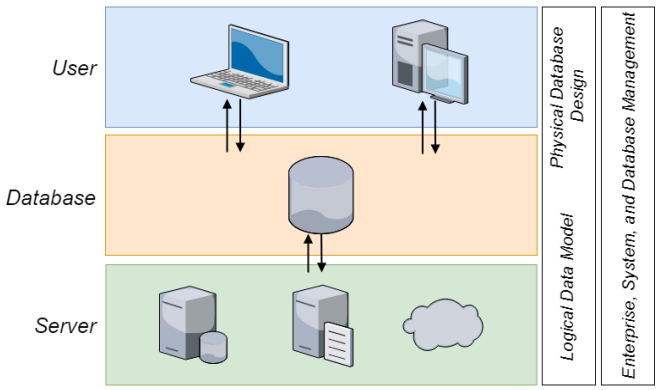

Figure 3. Data architecture.

Table 2.Candidate of data entity.

Business Entity	Data Entity
Research	Employees, Activities, Documents
Community service	Work Program, Organizational Unit, Document
Education (Workshop)	Work Program, Organizational Unit, Document
Products and Services for Biopharmaceutical Fields	Organizational Unit, Employee, Student / General, Request, Service, Document
Accounting and Financial Management	Organizational Unit, Financial Report, Fund Disbursement, Employees
HR Management	Employees, Resignation, Performance, Salary, Training, Licensing
Facilities and Infrastructure Management	Employees, Animals / Consumables, Organizational Units, Goods, Inventories, Procurement, Loans, Students / General, Rooms, Destruction
Monitoring	Employees, Services, Financial Reports, Activities, Inventories, Work Programs
Secretariat Management	Employees, Letters, Documents

Data entities that have been identified will then be modeled in the Entity Relationship Diagram (ERD) model. ERD can show the relationship between data entities and systems also relationship between data entities themselves. Domain model class diagram is also created to identify data entities (in this modeling called domain classes) and associations between domain classes in object-oriented [4]. Both modelings is carried out to support implementation using relational databases and object-oriented programming

4.3.2. Applications Architecture. This step will determine the application candidates needed by Trop BRC IPB based on an analysis of data entities and business entities obtained from data architecture step. Eight application candidates are resulted from this analysis to support the Trop BRC IPB business process which can be seen in Table 3.

Table 3.Applications candidate.

Code	Applications Candidate	Description
S1	Researcher Management Information System	Information system that manages data and activity documents carried out by researchers
S2	Information System for Product and Services	An information system that manages the entire service delivery process and enables online service requests
S3	Accounting Management Information System	An information system that manages financial data and prepares financial statements and balance sheets
S4	HR Management Information System	Information system that manages employee data along with employee performance and capability reports
S5	Facility and Infrastructure Management Information System	An information system that manages inventory and facilities data and supports inventory procurement, reservation and destruction activities
S6	Executive Information System	An information system that allows top managers to carry out business functions, monitor ongoing activities and current internal conditions of Trop BRC IPB.
S7	Secretariat Management Information System	Information system that manages mailings and archiving meetings and work activities documents
S8	Work Program Management Information System	An information system that manages work programs carried out by units and divisions, including program data collection, reporting of activities, and archiving of activity documents

Application candidates are related to organizational units in the form of a matrix to see application support for organizational units. The results of the matrix indicate that all organizational units have their respective roles in the application in accordance with their duties and authority. The application candidates are also related to business activities in the form of a matrix to determine the scope of each candidate application for business activities. The results of the analysis indicate that almost all business activities are covered by all application candidates so that the eight candidate applications can be declared as application recommendations.

The next step is to create usecase diagrams, activity diagrams, and sequence diagrams to show the flow, interaction, and activities of the actors and objects in the system based on systematic time sequences. The final step is to analyze the impact of developing application recommendations on current applications (legacy evolution system). The impact of each application candidate will be categorized into four categories, namely leave the system unchanged and continue with regular maintenance (R), scrap the system completely (SR), re-engineer the system to improve its maintainability (RE), and replace all part of the system with a new system (RA) [2]. The results of the impact analysis that carried out can be seen in Table 4.

Table 4. Application recomendations impact on current system/ applications.

Applications Recommendation	Current Application	Impact	Description
-	Trop BRC IPB website	R	Current system maintenance
Researcher MIS	-	RA	Development of new information systems
IS for Product and Service Services	SIMLAB	SR	Transition of service data management functions to new information systems
Accounting MIS	-	RA	Development of new information systems
HR MIS	-	RA	Development of new information systems
Facility and Infrastructure MIS	SIMLAB	SR	Transition of lab tools and materials data management function to the new information system
EIS	-	RA	Development of new information systems
Secretariat MIS	-	RA	Development of new information systems
Work Program MIS	-	RA	Development of new information systems

4.3.3. Technology Architecture. The first step at this stage is to define the technology principles and determine the technology platform. The principle of technology is defined by considering the development of information technology, business models, data architecture, application architecture, systems and existing technologies as well as the requests and findings of business people within the organization (Utomo 2014). The technology principles used can be seen in Table 5. These principles are then used to determine the technology platform prepared (Table 6). The second step at this stage is to describe the design of the IPB Trop BRC network architecture as shown in Figure 4.

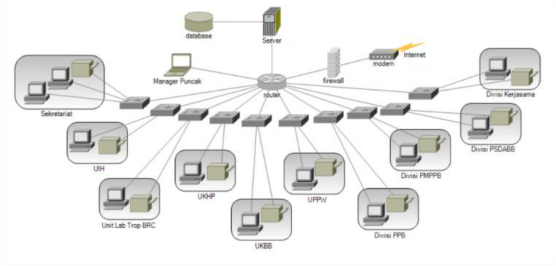

Figure 4. Technology architecture.

Table 5. Technology principle.

Platform Type	Principle
Operating System	1) Familiar or easy to use (user-friendly) 2) Supports the software and hardware needed for the built application 3) Have a license 4) Are compatible and support the network
Hardware	1) It is reliable and has a high level of availability 2) Independent of certain technology and brand features. 3) Meet the needs of the application to be built
Communication and Network	1) Provided with an adequate bandwidth. 2) Has a standard protocol to support network services and real-time access to information. 3) The internet is used as the main technology for sharing data through applications that will be built.
Software	1) Application development has a scale of importance 2) Familiar or easy to use (user-friendly) 3) Has standardized and updated documentation 4) Application development takes into account the needs of performance, users and costs 5) Application development starts from a small scale and could be developed
Security	1) Access rights are verified using keywords 2) Security requirements include secrecy, availability, and integrity
Data Management	1) Data is easily accessible and easy to understand 2) An integrated database management system between applications and fulfill Trop BRC IPB requirements 3) Using standardized data formats

Table 6.Prepared Technology Platform.

Hardware	Software	Communication
1 Computer • Compatible PC • Server 2 Input • Mouse • Keyboard • Scanner 3 Output • Printer • Monitor 4 Storage • Hard Disk Drive • Removable Drive • Hard Copy	1 Operating System • Windows 2 Spreadsheet • Microsoft Excel 3 Word Processing • Microsoft Word • Pdf reader 4 DBMS • MySQL 5 Programming Language • Java • PHP 6 Web Browser • Firefox/Google Chrome	1 Network • LAN/WLAN • Wifi • Internet 2 Phone 3 Messenger Applications 4 Cloud Drive

4.4. Implementation/Migrations Plans

4.4.1. Determine Priorities for Developing Applications Recommendation. This stage will determine the priority of developing applications recommendations by considering a number of conditions as priority selection criteria. Therefore, the priority determination method that is best used is the Analytical Hierarchy Process (AHP) method. The AHP method can break down the complexity of the decision-making process that occurs due to a large number of criteria that considered is quite a lot, by arranging the parts or components of the situation in the hierarchical structure [7].

Components that are modeled in the AHP hierarchy structure include goals, criteria, and alternatives. In this case, the goal is to determine the priority of developing information system recommendations. The criteria chosen to achieve this goal are urgency, time to work, cost, technology (user-friendly), and independence. These criteria are chosen based on the principles of technology used [6]. The alternative is the eight applications recommendations that have been defined at the application architecture stage.

The next step is to collect data using a questionnaire for employees and stakeholders from Trop BRC IPB to determine the priority ratio between criteria and also between applications based on each criterion. The priority ratio data will then look for the priority using the concept of eigenvalues. Example calculations for comparison of criteria can be seen in Table 7. The results of the calculation of the eigenvalues will then be sorted and obtained the priority of the application development candidates.

Table 7. Priority weight value with 2.85% consistency ratio.

Criteria	Urgency	Time	Cost	User-Friendly	Independence
Urgency	1.000000	6.804092	6.804092	8.276773	7.113787
Time	0.146970	1.000000	1.000000	0.584804	2.027401
Cost	0.146970	1.000000	1.000000	0.775656	2.027401
User-Friendly	0.120820	1.709976	1.289232	1.000000	2.758924
Independence	0.140572	0.493242	0.493242	0.362460	1.000000
Weight Priority	0.640335	0.089553	0.094079	0.121605	0.054428

The applications development priority resulted by using AHP in fact conflict with the value chain model that previously made (Figure 2), there is a discrepancy between the priority resulted and the level of importance of the business function covered by the applications. This proves that the AHP results that have been carried out have not succeeded in giving the proper development priority in Trop BRC IPB. Factors that might influence this are unsuitable questionnaire data collection techniques, error in criteria selection, and a deficient number of iterations. Analysis on Trop BRC IPB business function combined with AHP result is must be done. Applications recommendation's development order resulted by this analysis thus being compared with the development order resulted by AHP. The comparison can be seen in Table 8.

4.4.2. Estimating Applications Development Cost. At this stage, the costs to be estimated include the time and amount of human resources needed by Trop BRC IPB to develop all applications recommendation. The method used to calculate the estimation in this study is the function point analysis (FPA) method. The calculation of the function point (FP), optimal schedule (OS), and optimal team size (OTS) is performed on each applications recommendation. The FP value per month used refers to [8] which is 8.90. The results of the optimal calculation of the obtained schedule are around 63.74 months or equivalent to 5.3 years with an optimal average of team size of two people. Table 9 shows the results of the calculation of function points (FP), person month (PM), and complete optimal schedule (OS).

Table 8. Applications development priority.

Priority Number	Result by Using AHP		Result by Analysis of Business Model and AHP	
	Code	Applications	Code	Applications
1	S8	Work Program MIS	S1	Researcher MIS
2	S6	EIS	S8	Work Program MIS
3	S3	Accounting MIS	S2	IS for Product and Services
4	S4	HR MIS	S3	Accounting MIS
5	S1	Researcher MIS	S4	HR MIS
6	S7	Secretariat MIS	S5	Facility and Infrastructure MIS
7	S2	IS for Product and Services	S7	Secretariat MIS
8	S5	Facility and Infrastructure MIS	S6	EIS

Table 9.FP value for each application.

Code	Applications Recommendation	Function Point	Person Month	Optimal Schedule
S1	Researcher MIS	143.82	16.1596	7.584571
S2	IS for Product and Services	171.00	19.2135	8.035075
S3	Accounting MIS	163.00	18.3146	7.907766
S4	HR MIS	167.89	18.8641	7.986065
S5	Facility and Infrastructure MIS	240.00	26.9663	8.996253
S6	EIS	259.70	29.1798	9.235957
S7	Secretariat MIS	102.82	11.5528	6.781886
S8	Work Program MIS	123.42	13.8674	7.207530
	Total	1371.65	154.1181	63.73510

4.4.3. Implementation Strategy. This stage determines the strategy for implementing information system recommendations. The strategies that can be done by Trop BRC IPB include:

- Provision of PCs and networks, stable internet connections, and other supporting devices for each organizational unit.
- Standardizing the operating system and software on all PCs and laptops owned by the Trop BRC IPB that supports information systems.
- Maintenance of hardware, networks and other supporting devices owned by Trop BRC IPB.
- Maintenance and addition of servers to support information systems.
- Procurement of storage space for servers that are suitable for server conditions.

5. Conclusion and Future Works

This research has succeeded in defining application requirements based on enterprise architecture to support business functions in Trop BRC IPB. This research has defined nine business functions including its decompositions and 23 data entities grouped into each business entity. The data entity analysis produced eight information system recommendations. The results of the application architecture then resulted in a network structure plan for the Trop BRC IPB and the technology platform principle. Ordering information system development priorities are then carried out using AHP and business model analysis with the results of the first priority falling on the researcher management information system. The system development costs are estimated using a function point analysis with an estimated time of 63.74 months and a team size of two people. Application implementation strategies to support the successful implementation of Trop BRC IPB that is the

provision of technology that supports applications in each organizational unit, standardizes technology, maintenance, technology, and provides storage space for servers.

Information system development planning in this research should proceed to the implementation stage by adding a more detailed analysis of each information system recommendation. The data retrieval method should be considered in the use of AHP for determining priorities and if the results are not satisfactory, it is better to redo the data retrieval. Future works on information system development planning for a research center should be done using other enterprise architecture framework as a comparison to discovering more appropriate plans for research centers architecture.

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